

DescriptionMETHODS OF PRODUCING SECRETED RECEPTOR ANALOGS AND  
BIOLOGICALLY ACTIVE DIMERIZED POLYPEPTIDE FUSIONS

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Cross Reference to Related Application

This application is a continuation-in-part of U.S. Application Serial No. 07/347,291, filed May 2, 1989, which is a continuation-in-part application of U.S. Application Serial No. 146,877, filed January 22, 1988, now abandoned.

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Technical Field

The present invention is generally directed 15 toward the expression of proteins, and more specifically, toward the expression of growth factor receptor analogs and biologically active dimerized polypeptide fusions.

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In higher eucaryotic cells, the interaction between receptors and ligands (e.g., hormones) is of central importance in the transmission of and response to a variety of extracellular signals. It is generally accepted that hormones and growth factors elicit their 25 biological functions by binding to specific recognition sites (receptors) in the plasma membranes of their target cells. Upon ligand binding, a receptor undergoes a conformational change, triggering secondary cellular responses that result in the activation or inhibition of 30 intracellular processes. The stimulation or blockade of such an interaction by pharmacological means has important therapeutic implications for a wide variety of illnesses.

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Ligands fall into two classes: those that have stimulatory activity, termed agonists; and those that 35 block the effects elicited by the original ligands, termed antagonists. The discovery of agonists that differ in structure and composition from the original ligand may be

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medically useful. In particular, agonists that are smaller than the original ligand may be especially useful. The bioavailability of these smaller agonists may be greater than that of the original ligand. This may be of 5 particular importance for topical applications and for instances when diffusion of the agonist to its target sites is inhibited by poor circulation. Agonists may also have slightly different spectra of biological activity and/or different potencies, allowing them to be used in 10 very specific situations. Agonists that are smaller and chemically simpler than the native ligand may be produced in greater quantity and at lower cost. The identification of antagonists which specifically block, for example, growth factor receptors has important pharmaceutical 15 applications. Antagonists that block receptors against the action of endogenous, native ligand may be used as therapeutic agents for conditions including atherosclerosis, autocrine tumors, fibroplasia and keloid formation.

20 The discovery of new ligands that may be used in pharmaceutical applications has centered around designing compounds by chemical modification, complete synthesis, and screening potential ligands by complex and costly screening procedures. The process of designing a new 25 ligand usually begins with the alteration of the structure of the original effector molecule. If the original effector molecule is known to be chemically simple, for example, a catecholamine or prostaglandin, the task is relatively straightforward. However, if the ligand is 30 structurally complex, for example, a peptide hormone or a growth factor, finding a molecule which is functionally equivalent to the original ligand becomes extremely difficult.

35 Currently, potential ligands are screened using radioligand binding methods (Lefkowitz et al., Biochem. Biophys. Res. Comm. 60: 703-709, 1974; Aurbach et al., Science 186: 1223-1225, 1974; Atlas et al., Proc. Natl.

Acad. Sci. USA 71: 4246-4248, 1974). Potential ligands can be directly assayed by binding the radiolabeled compounds to responsive cells, to the membrane fractions of disrupted cells, or to solubilized receptors.

- 5 Alternatively, potential ligands may be screened by their ability to compete with a known labeled ligand for cell surface receptors.

The success of these procedures depends on the availability of reproducibly high quality preparations of

- 10 membrane fractions or receptor molecules, as well as the isolation of responsive cell lines. The preparation of membrane fractions and soluble receptor molecules involves extensive manipulations and complex purification steps.

15 The isolation of membrane fractions requires gentle manipulation of the preparation, a procedure which does not lend itself to commercial production. It is very difficult to maintain high biological activity and biochemical purity of receptors when they are purified by classical protein chemistry methods. Receptors, being

- 20 integral membrane proteins, require cumbersome purification procedures, which include the use of detergents and other solvents that interfere with their biological activity. The use of these membrane preparations in ligand binding assays typically results in 25 low reproducibility due to the variability of the membrane preparations.

As noted above, ligand binding assays require the isolation of responsive cell lines. Often, only a limited subset of cells is responsive to a particular 30 agent, and such cells may be responsive only under certain conditions. In addition, these cells may be difficult to grow in culture or may possess a low number of receptors. Currently available cell types responsive to platelet-derived growth factor (PDGF), for example, contain only a 35 low number (up to  $4 \times 10^5$ ; see Bowen-Pope and Ross, J. Biol. Chem. 257: 5161-5171, 1982) of receptors per cell,

thus requiring large numbers of cells to assay PDGF analogs or antagonists.

Presently, only a few naturally-occurring secreted receptors, for example, the interleukin-2 receptor (IL-2-R) have been identified. Rubin et al. (J. Immun. 135: 3172-3177, 1985) have reported the release of large quantities of IL-2-R into the culture medium of activated T-cell lines. Bailon et al. (Bio/Technology 5: 1195-1198, 1987) have reported the use of a matrix-bound interleukin-2 receptor to purify recombinant interleukin-2.

Three other receptors have been secreted from mammalian cells. The insulin receptor (Ellis et al., J. Cell Biol. 150: 14a, 1987), the HIV-1 envelope glycoprotein cellular receptor CD4 (Smith et al., Science 238: 1704-1707, 1987), the murine IL-7 receptor (Cell 60: 941-951, 1990) and the epidermal growth factor (EGF) receptor (Livneh et al., J. Biol. Chem. 261: 12490-12497, 1986) have been secreted from mammalian cells using truncated cDNAs that encode portions of the extracellular domains.

Naturally-occurring, secreted receptors have not been widely identified, and there have been only a limited number of reports of secreted recombinant receptors. Secreted receptors may be used in a variety of assays, which include assays to determine the presence of ligand in biological fluids and assays to screen for potential agonists and antagonists. Current methods for ligand screening and ligand/receptor binding assays have been limited to those using preparations of whole cells or cell membranes for as a source for receptor molecules. The low reproducibility and high cost of producing such preparations does not lend itself to commercial production. There is therefore a need in the art for a method of producing secreted receptors. There is a further need in the art for an assay system that permits high volume screening of compounds that may act on higher eucaryotic cells via specific surface receptors. This

assay system should be rapid, inexpensive and adaptable to high volume screening. The present invention discloses such a method and assay system, and further provides other related advantages.

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### Disclosure of Invention

Briefly stated, the present invention discloses methods for producing secreted receptor analogs, including receptor analogs and secreted platelet-derived growth factor receptor (PDGF-R) analogs. In addition, the present invention discloses methods for producing secreted biologically active dimerized polypeptide fusions.

Within one aspect of the invention a method for producing a secreted PDGF-R analog is disclosed, comprising (a) introducing into a eukaryotic host cell a DNA construct comprising a transcriptional promoter operatively linked to a secretory signal sequence followed downstream of and in proper reading frame with a DNA sequence encoding at least a portion of the ligand-binding domain of a PDGF-R, the portion including a ligand-binding domain; (b) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of a PDGF-R analog encoded by said DNA sequence; and (c) isolating the PDGF-R analog from the host cell.

25 Within one embodiment of the present invention,  
a PDGF-R analog comprising the amino acid sequence of  
<sup>Figures 1A-1B</sup>  
Figure 1 (Sequence ID Numbers 1 and 2) from isoleucine,  
number 29, to methionine, number 441, is secreted. Within  
another embodiment, a PDGF-R analog comprising the amino  
acid sequence of <sup>Figures 1A-1B</sup>  
Figure 1 (Sequence ID Numbers 1 and 2)  
from isoleucine, number 29 to lysine, number 531 is  
secreted. Within yet another embodiment of the invention,  
a PDGF-R analog comprising the amino acid sequence of  
<sup>Figures 1A-1B</sup>  
Figure 1 (Sequence ID Numbers 35 and 36) from glutamine,  
35 number 24 to glutamic acid, number 524 is secreted.

Yet another aspect of the present invention discloses a method for producing a secreted, biologically

active dimerized polypeptide fusion. The method generally comprises a) introducing into a eukaryotic host cell a DNA construct comprising a transcriptional promoter operatively linked to a secretory signal sequence followed 5 downstream by and in proper reading frame with a DNA sequence encoding a non-immunoglobulin polypeptide requiring dimerization for biological activity joined to a dimerizing protein; (b) growing the host cell in an appropriate growth medium under physiological conditions 10 to allow the secretion of a dimerized polypeptide fusion encoded by said DNA sequence; and (c) isolating the biologically active dimerized polypeptide fusion from the host cell.

Within one embodiment, the dimerizing protein is 15 yeast invertase. Within another embodiment, the dimerizing protein is at least a portion of an immunoglobulin light chain. Within another embodiment, the dimerizing protein is at least a portion of an immunoglobulin heavy chain.

In another aspect of the invention, a method is disclosed for producing a secreted, biologically active dimerized polypeptide fusion, comprising (a) introducing 20 into a eukaryotic host cell a first DNA construct comprising a transcriptional promoter operatively linked to a first secretory signal sequence followed downstream by and in proper reading frame with a first DNA sequence encoding a non-immunoglobulin polypeptide requiring dimerization for biological activity joined to an immunoglobulin light chain constant region; (b) 25 introducing into the host cell a second DNA construct comprising a transcriptional promoter operatively linked to a second secretory signal sequence followed downstream by and in proper reading frame with a second DNA sequence encoding an immunoglobulin heavy chain constant region 30; (c) growing the host cell in an appropriate growth medium under physiological conditions to allow the 35 domain selected from the group consisting of C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4;

(c) growing the host cell in an appropriate growth medium under physiological conditions to allow the

secretion of a dimerized polypeptide fusion encoded by said first and second DNA sequences; and (d) isolating the dimerized polypeptide fusion from the host cell. In one embodiment, the second DNA sequence further encodes an immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain. In a preferred embodiment, the second DNA sequence further encodes an immunoglobulin variable region joined upstream of and in proper reading frame with the immunoglobulin heavy chain constant region.

In another aspect of the invention, a method is disclosed for producing a secreted, biologically active dimerized polypeptide fusion, comprising (a) introducing into a eukaryotic host cell a first DNA construct comprising a transcriptional promoter operatively linked to a first secretory signal sequence followed downstream by and in proper reading frame with a first DNA sequence encoding a non-immunoglobulin polypeptide requiring dimerization for biological activity joined to an immunoglobulin heavy chain constant region domain selected from the group consisting of C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) introducing into the host cell a second DNA construct comprising a transcriptional promoter operatively linked to a second secretory signal sequence followed downstream by and in proper reading frame with a second DNA sequence encoding an immunoglobulin light chain constant region; (c) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of a dimerized polypeptide fusion encoded by said first and second DNA sequences; and (d) isolating the dimerized polypeptide fusion from the host cell. In one embodiment, the first DNA sequence further encodes an immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain. In a preferred embodiment, the second DNA sequence further encodes an immunoglobulin variable region joined upstream

of and in proper reading frame with the immunoglobulin light chain constant region.

In another aspect of the invention, a method is disclosed for producing a secreted, biologically active 5 dimerized polypeptide fusion, comprising (a) introducing into a eukaryotic host cell a DNA construct comprising a transcriptional promoter operatively linked to a secretory signal sequence followed downstream by and in proper reading frame with a DNA sequence encoding a non- 10 immunoglobulin polypeptide requiring dimerization for biological activity joined to an immunoglobulin heavy chain constant region domain selected from the group consisting of C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) growing the host cell in an appropriate growth medium under physiological 15 conditions to allow the secretion of a dimerized polypeptide fusion encoded by said first and second DNA sequences; and (c) isolating the biologically active dimerized polypeptide fusion from the host cell. In one embodiment, the DNA sequence further encodes an 20 immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain.

In another aspect of the invention, a method is disclosed for producing a secreted, biologically active 25 dimerized polypeptide fusion, comprising (a) introducing into a eukaryotic host cell a first DNA construct comprising a transcriptional promoter operatively linked to a first secretory signal sequence followed downstream by and in proper reading frame with a first DNA sequence 30 encoding a first polypeptide chain of a non-immunoglobulin polypeptide dimer requiring dimerization for biological activity joined to an immunoglobulin heavy chain constant region domain, selected from the group consisting of C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) introducing into the host cell a 35 second DNA construct comprising a transcriptional promoter operatively linked to a second secretory signal sequence followed downstream by and in proper reading frame with a

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second DNA sequence encoding a second polypeptide chain of the non-immunoglobulin polypeptide dimer joined to an immunoglobulin light chain constant region domain; (c) growing the host cell in an appropriate growth medium  
 5 under physiological conditions to allow the secretion of a dimerized polypeptide fusion encoded by said first and second DNA sequences wherein said dimerized polypeptide fusion exhibits biological activity characteristic of said non-immunoglobulin polypeptide dimer; and (d) isolating  
 10 the dimerized polypeptide fusion from the host cell. In one embodiment the first DNA sequence further encodes an immunoglobulin heavy chain hinge region domain wherein the hinge region is joined to the immunoglobulin heavy chain constant region domain.

15 Within one embodiment of the present invention, a biologically active dimerized polypeptide fusion comprising the amino acid sequence of <sup>Figures IA-IB</sup> ~~Figure 1~~ (Sequence ID Numbers 1 and 2) from isoleucine, number 29, to methionine, number 441, is secreted. Within another  
 20 embodiment, a biologically active dimerized polypeptide fusion comprising the amino acid sequence of <sup>Figure IA-IB</sup> ~~Figure 1~~ (Sequence ID Numbers 1 and 2) from isoleucine, number 29 to lysine, number 531 is secreted. Within another embodiment of the invention, a biologically active  
 25 dimerized polypeptide fusion comprising the amino acid sequence of <sup>Figures II A-II B</sup> ~~Figure 11~~ (Sequence ID Numbers 35 and 36) from glutamine, number 24 to glutamic acid, number 524 is secreted. Within yet another embodiment of the invention, a biologically active dimerized polypeptide fusion  
 30 comprising the amino acid sequence of <sup>Figures IA-IB</sup> ~~Figure 1~~ (Sequence ID Numbers 1 and 2) from isoleucine, number 29 to lysine, number 531 dimerized to the amino acid sequence of <sup>Figures II A-II B</sup> ~~Figure 11~~ (Sequence ID Numbers 35 and 36) from glutamine, number 24 to glutamic acid, number 524 is secreted.

35 In yet another aspect of the invention, a method is disclosed for producing a secreted receptor analog, comprising (a) introducing into a eukaryotic host cell a

DNA construct comprising a transcriptional promoter operatively linked to at least one secretory signal sequence followed downstream by and in proper reading frame with a DNA sequence encoding a ligand-binding domain  
5 of a receptor requiring dimerization for biological activity joined to a dimerizing protein; (b) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of a receptor analog encoded by said DNA sequence; and (c)  
10 isolating the receptor analog from the host cell.

In yet another aspect of the invention, a method is disclosed for producing a secreted receptor analog, comprising (a) introducing into a eukaryotic host cell a first DNA construct comprising a transcriptional promoter  
15 operatively linked to a first secretory signal sequence followed downstream by and in proper reading frame with a first DNA sequence encoding a ligand-binding domain of a receptor requiring dimerization for biological activity joined to an immunoglobulin light chain constant region;  
20 (b) introducing into the host cell a second DNA construct comprising a transcriptional promoter operatively linked to a second secretory signal sequence followed downstream by and in proper reading frame with a second DNA sequence encoding an immunoglobulin heavy chain constant region  
25 domain, selected from the group consisting of C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (c) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of a receptor analog encoded by said first and second DNA sequences; and (d) isolating the receptor  
30 analog from the host cell. In one embodiment, the second DNA sequence further encodes an immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain. In a preferred embodiment, the second DNA sequence further encodes an  
35 immunoglobulin variable region joined upstream of and in proper reading frame with the immunoglobulin heavy chain constant region.

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In another aspect of the invention, a method is disclosed for producing a secreted receptor analog, comprising (a) introducing into a eukaryotic host cell a DNA construct comprising a transcriptional promoter operatively linked to a secretory signal sequence followed downstream by and in proper reading frame with a DNA sequence encoding a ligand-binding domain of a receptor requiring dimerization for biological activity joined to an immunoglobulin heavy chain constant region domain, 5 selected from the group C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of the receptor analog; and (c) isolating the receptor analog from the host cell. In one embodiment, the DNA sequence 10 further encodes an immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain.

In another aspect of the invention, a method is disclosed for producing a secreted receptor analog, 20 comprising (a) introducing into a eukaryotic host cell a first DNA construct comprising a transcriptional promoter operatively linked to a first secretory signal sequence followed downstream of and in proper reading frame with a first DNA sequence encoding a ligand-binding domain of a receptor requiring dimerization for biological activity joined to an immunoglobulin heavy chain constant region domain, selected from the group C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) introducing into the host cell a second DNA construct 25 comprising a transcriptional promoter operatively linked to a second secretory signal sequence followed downstream by and in proper reading frame with a second DNA sequence encoding an immunoglobulin light chain constant region; (c) growing the host cell in an appropriate growth medium under physiological conditions to allow the secretion of a receptor analog encoded by said first and second DNA sequences; and (d) isolating the receptor analog from the host cell. In one embodiment, the first DNA sequence

further encodes an immunoglobulin heavy chain hinge region wherein the hinge region is joined to the heavy chain constant region domain. In a preferred embodiment, the second DNA sequence further encodes an immunoglobulin 5 variable region joined upstream of and in proper reading frame with the immunoglobulin light chain constant region.

In another aspect of the invention, a method is disclosed for producing a secreted receptor analog, comprising (a) introducing into a eukaryotic host cell a 10 first DNA construct comprising a transcriptional promoter operatively linked to a first secretory signal sequence followed downstream in proper reading frame by a first DNA sequence encoding a first polypeptide chain of a ligand-binding domain of a receptor requiring dimerization for 15 biological activity joined to an immunoglobulin heavy chain constant region domain, selected from the group C<sub>H</sub>1, C<sub>H</sub>2, C<sub>H</sub>3, and C<sub>H</sub>4; (b) introducing into the host cell a second DNA construct comprising a transcriptional promoter operatively linked to a second secretory signal sequence 20 followed downstream by and in proper reading frame with a second DNA sequence encoding a second polypeptide chain of the ligand-binding domain of said receptor joined to an immunoglobulin light chain constant region domain; (c) growing the host cell in an appropriate growth medium 25 under physiological conditions to allow the secretion of a receptor analog encoded by said first and second DNA sequences; and (d) isolating the receptor analog from the host cell. In one embodiment the first DNA sequence further encodes an immunoglobulin heavy chain hinge region 30 domain wherein the hinge region is joined to the immunoglobulin heavy chain constant region domain.

Host cells for use in the present invention include cultured mammalian cells and fungal cells. In a preferred embodiment strains of the yeast Saccharomyces cerevisiae are used as host cells. Within another preferred embodiment cultured rodent myeloma cells are used as host cells.

Within one embodiment of the present invention, a receptor analog is a PDGF-R analog comprising the amino acid sequence of Figure 1 (Sequence ID Numbers 1 and 2) from isoleucine, number 29, to methionine, number 441.

5 Within another embodiment a PDGF-R analog comprises the amino acid sequence of Figure 1 (Sequence ID Numbers 1 and 2) from isoleucine, number 29, to lysine, number 531. Within another embodiment of the invention, a PDGF-R analog comprises the amino acid sequence of Figure 11

10 (Sequence ID Numbers 35 and 36) from glutamine, number 24 to glutamic acid, number 524 is secreted. Within yet another embodiment of the invention, a PDGF-R analog comprises the amino acid sequence of Figure 1 (Sequence ID Numbers 1 and 2) from isoleucine, number 29 to lysine,

15 number 531 and the amino acid sequence of Figure 11 (Sequence ID Numbers 35 and 36) from glutamine, number 24 to glutamic acid, number 524 is secreted.

PDGF-R analogs produced by the above-disclosed methods may be used, for instance, within a method for

20 determining the presence of human PDGF or an isoform thereof in a biological sample.

A method for determining the presence of human PDGF or an isoform thereof in a biological sample is disclosed and comprises (a) incubating a polypeptide

25 comprising a PDGF receptor analog fused to a dimerizing protein with a biological sample suspected of containing PDGF or an isoform thereof under conditions that allow the formation of receptor/ligand complexes; and (b) detecting the presence of receptor/ligand complexes, and therefrom

30 determining the presence of PDGF or an isoform thereof. Suitable biological samples in this regard include blood, urine, plasma, serum, platelet and other cell lysates, platelet releasates, cell suspensions, cell-conditioned culture media, and chemically or physically separated

35 portions thereof.

These and other aspects of the present invention will become evident upon reference to the following detailed description and attached drawings.

5 Brief Description of the Drawings

illustrate Figures 10-16 (Sequence ID Numbers 1 and 2) illustrates the nucleotide sequence of a representative PDGF  $\beta$ -receptor cDNA and the derived amino acid sequence of the primary translation product and corresponds to Sequence ID Number 1). Numbers above the lines refer to the nucleotide sequence; numbers below the lines refer to the amino acid sequence.

Figure 2 illustrates the construction of pBTL10, pBTL11 and pBTL12.

15 Figure 3 illustrates the construction of pcBS22.

Figure 4 illustrates the construction of pBTL13 and pBTL14.

Figure 5 illustrates the construction of pBTL15.

20 Figure 6 illustrates the construction of pBTL22 and pBTL26.

Figure 7 illustrates the construction of pSDL114. Symbols used are S.S., signal sequence,  $C_k$ , immunoglobulin light chain constant region sequence;  $\mu$  prom,  $\mu$  promoter,  $\mu$  enh,  $\mu$  enhancer.

25 Figure 8 illustrates the construction of pSDLB113. Symbols used are S.S., signal sequence;  $C_{H1}$ ,  $C_{H2}$ ,  $C_{H3}$ , immunoglobulin heavy chain constant region domain sequences; H, immunoglobulin heavy chain hinge region sequence; M, immunoglobulin membrane anchor sequences;  $C_{\gamma 1M}$ , immunoglobulin heavy chain constant region and membrane anchor sequences.

30 Figure 9 illustrates the constructions pBTL115, pBTL114, p $\phi$ 5V $H$ HuC $\gamma 1M$ -neo, p1C $\phi$ 5V $K$ HuC $K$ -neo. Symbols used are set forth in Figures 7 and 8, and also include  $L_H$ , mouse immunoglobulin heavy chain signal sequence;  $V_H$ , mouse immunoglobulin heavy chain variable region sequence; E, mouse immunoglobulin heavy chain enhancer sequence;  $L_K$ ,

mouse immunoglobulin light chain signal sequence;  $\phi$ 5V<sub>K</sub>, mouse immunoglobulin light chain variable region sequence; Neo<sup>R</sup>, *E. coli* neomycin resistance gene.

Figure 10 illustrates the constructions Zem229R,  
5 p $\phi$ 5V<sub>H</sub>Fab-neo and pWKI. Symbols used are set forth in  
Figure 9. Figures 11A-11D illustrate

10 Figure 11 illustrates the sequence of a representative PDGF  $\alpha$ -receptor cDNA and the deduced amino acid sequence (using standard one-letter codes) encoded by the cDNA and corresponds to Sequence ID Numbers 35 and 36. Numbers at the ends of the lines refer to nucleotide positions. Numbers below the sequence refer to amino acid positions.

15 Figure 12 illustrates the assembly of a cDNA molecule encoding a PDGF  $\alpha$ -receptor. Complementary DNA sequences are shown as lines. Only those portions of the vectors adjacent to the cDNA inserts are shown.

#### Detailed Description of the Invention

20 Prior to setting forth the invention, it may be helpful to an understanding thereof to set forth definitions of certain terms to be used hereinafter.

25 DNA Construct: A DNA molecule, or a clone of such a molecule, either single- or double-stranded that has been modified through human intervention to contain segments of DNA combined and juxtaposed in a manner that as a whole would not otherwise exist in nature.

30 DNA constructs contain the information necessary to direct the expression and/or secretion of DNA sequences encoding polypeptides of interest. DNA constructs will generally include promoters, enhancers and transcription terminators. DNA constructs containing the information necessary to direct the secretion of a polypeptide will also contain at least one secretory signal sequence.

35 Secretory Signal Sequence: A DNA sequence encoding a secretory peptide. A secretory peptide is an amino acid sequence that acts to direct the secretion of a

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mature polypeptide or protein from a cell. Secretory peptides are characterized by a core of hydrophobic amino acids and are typically (but not exclusively) found at the amino termini of newly synthesized proteins. Very often 5 the secretory peptide is cleaved from the mature protein during secretion. Such secretory peptides contain processing sites that allow cleavage of the signal peptides from the mature proteins as it passes through the secretory pathway. Processing sites may be encoded within 10 the signal peptide or may be added to the signal peptide by, for example, in vitro mutagenesis. Certain secretory peptides may be used in concert to direct the secretion of polypeptides and proteins. One such secretory peptide that may be used in combination with other secretory 15 peptides is the third domain of the yeast Barrier protein.

Receptor Analog: A non-immunoglobulin polypeptide comprising a portion of a receptor which is capable of binding ligand and/or <sup>P</sup> are recognized by anti-receptor antibodies. The amino acid sequence of the 20 receptor analog may contain additions, substitutions or deletions as compared to the native receptor sequence. A receptor analog may be, for example, the ligand-binding domain of a receptor joined to another protein. Platelet-derived growth factor receptor (PDGF-R) analogs may, for 25 example, comprise a portion of a PDGF receptor capable of binding anti-PDGF receptor antibodies, PDGF, PDGF isoforms, PDGF analogs, or PDGF antagonists.

Dimerizing Protein: A polypeptide chain having affinity for a second polypeptide chain, such that the two 30 chains associate under physiological conditions to form a dimer. The second polypeptide chain may be the same or a different chain.

Biological activity: A function or set of activities performed by a molecule in a biological context 35 (i.e., in an organism or an in vitro facsimile thereof). Biological activities may include the induction of extracellular matrix secretion from responsive cell lines,

the induction of hormone secretion, the induction of chemotaxis, the induction of mitogenesis, the induction of differentiation, or the inhibition of cell division of responsive cells. A recombinant protein or peptide is  
5 considered to be biologically active if it exhibits one or more biological activities of its native counterpart.

Ligand: A molecule capable of being bound by the ligand-bindind domain of a receptor or by a receptor analog. The molecule may be chemically synthesized or may  
10 occur in nature. Ligands may be grouped into agonists and antagonists. Agonists are those molecules whose binding to a receptor induces the response pathway within a cell. Antagonists are those molecules whose binding to a receptor blocks the response pathway within a cell.  
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Joined: Two or more DNA coding sequences are said to be joined when, as a result of in-frame fusions between the DNA coding sequences or as a result of the removal of intervening sequences by normal cellular processing, the DNA coding sequences are translated into a  
20 polypeptide fusion.

As noted above, the present invention provides methods for producing biologically active dimerized polypeptide fusions and secreted receptor analogs, which  
25 include, for example, PDGF receptor analogs. Secreted receptor analogs may be used to screen for new compounds that act as agonists or antagonists when interacting with cells containing membrane-bound receptors. In addition, the methods of the present invention provide dimerized  
30 non-immunoglobulin polypeptide fusions of therapeutic value that are biologically active only as dimers. Moreover, the present invention provides methods of producing polypeptide dimers that are biologically active only as non-covalently associated dimers. Secreted,  
35 biologically active dimers that may be produced using the present invention include nerve growth factor, colony

stimulating factor-1, factor XIII, and transforming growth factor  $\beta$ .

As used herein, the ligand-binding domain of a receptor is that portion of the receptor that is involved with binding the natural ligand. While not wishing to be bound by theory, the binding of a natural ligand to a receptor is believed to induce a conformational change which elicits a response to the change within the response pathway of the cell. For membrane-bound receptors, the ligand-binding domain is generally believed to comprise the extracellular domain for the receptor. The structure of receptors may be predicted from the primary translation products using the hydrophobicity plot function of, for example, P/C Gene or Intelligenetics Suite (Intelligenetics, Mt. View, CA) or may be predicted according to the methods described, for example, by Kyte and Doolittle, J. Mol. Biol. 157:105-132, 1982). The ligand-binding domain of the PDGF  $\beta$ -receptor, for example, has been predicted to include amino acids 29-531 of the published sequence (Gronwald et al., ibid.). The ligand-binding domain of the PDGF  $\alpha$ -receptor has been predicted to include amino acids 25-500 of the published  $\alpha$ -receptor sequence (Matsui et al., ibid.). As used herein, the ligand-binding domain of the PDGF  $\beta$ -receptor includes amino acids 29-441 of the sequence of Figure 1 (Sequence ID Number 1) and C-terminal extensions up to and including amino acid 531. The ligand-binding domain of the PDGF  $\alpha$ -receptor is understood to include amino acids 24-524 of Figure 11 (Sequence ID Numbers 35 and 36).

Receptor analogs that may be used in the present invention include the ligand-binding domains of the epidermal growth factor receptor (EGF-R) and the insulin receptor. As used herein, a ligand-binding domain is that portion of the receptor that is involved in binding ligand and is generally a portion or essentially all of the extracellular domain that extends from the plasma membrane into the extracellular space. The ligand-binding domain

of the EGF-R, for example, resides in the extracellular domain. EGF-R dimers have been found to exhibit higher ligand-binding affinity than EGF-R monomers (Bonisch-Schnetzler and Pilch, Proc. Natl. Acad. Sci. USA 84:7832-  
5 7836, 1987). The insulin receptor (Ullrich et al., Nature 313:756-761, 1985) requires dimerization for biological activity.

Another example of a receptor that may be secreted from a host cell is a platelet-derived growth factor receptor (PDGF-R). Two classes of PDGF-Rs, which recognized different isoforms of PDGF, have been identified. (PDGF is a disulfide-bonded, two-chain molecule, which is made up of an A chain and a B chain. These chains may be combined as AB heterodimers, AA homodimers or BB homodimers. These dimeric molecules are referred to herein as "isoforms".) The  $\beta$ -receptor (PDGF $\beta$ -R), which recognizes only the BB isoform of PDGF (PDGF-BB), has been described (Claesson-Welsh et al., Mol. Cell. Biol. 8:3476-3486, 1988; Gronwald et al., Proc. Natl. Acad. Sci. USA 85:3435-3439, 1988). The  $\alpha$ -receptor (PDGF $\alpha$ -R), which recognizes all three PDGF isoforms (PDGF-AA, PDGF-AB and PDGF-BB), has been described by Matsui et al. (Science 243:800-804, 1989) and Kelly and Murray (pending commonly assigned U.S. Patent Application Serial No. 25 07/355,018, which is incorporated herein by reference). The primary translation products of these receptors indicate that each includes an extracellular domain implicated in the ligand-binding process, a transmembrane domain, and a cytoplasmic domain containing a tyrosine kinase activity.

The present invention provides a standardized assay system, not previously available in the art, for determining the presence of PDGF, PDGF isoforms, PDGF agonists or PDGF antagonists using a secreted PDGF receptor analogs. Such an assay system will typically involve combining the secreted PDGF receptor analog with a biological sample under physiological conditions which

permit the formation of receptor-ligand complexes, followed by detecting the presence of the receptor-ligand complexes. The term physiological conditions is meant to include those conditions found within the host organism  
5 and include, for example, the conditions of osmolarity, salinity and pH. Detection may be achieved through the use of a label attached to the PDGF receptor analog or through the use of a labeled antibody which is reactive with the receptor analog or the ligand. A wide variety of  
10 labels may be utilized, such as radionuclides, fluorophores, enzymes and luminescers. Receptor-ligand complexes may also be detected visually, i.e., in immunoprecipitation assays which do not require the use of a label. This assay system provides secreted PDGF  
15 receptor analogs that may be utilized in a variety of screening assays for, for example, screening for analogs of PDGF. The present invention also provides a methods for measuring the level of PDGF and PDGF isoforms in biological fluids.

20 As noted above, the present invention provides methods for producing dimerized polypeptide fusions that require dimerization for biological activity or enhancement of biological activity. Polypeptides requiring dimerization for biological activity include, in  
25 addition to certain receptors, nerve growth factor, colony-stimulating factor-1 (CSF-1), transforming growth factor  $\beta$  (TGF- $\beta$ ), PDGF, and factor XIII. Nerve growth factor is a non-covalently linked dimer (Harper et al., J. Biol. Chem. 257: 8541-8548, 1982). CSF-1, which  
30 specifically stimulates the proliferation and differentiation of cells of mononuclear phagocytic lineage, is a disulfide-bonded homodimer (Retternmier et al., Mol. Cell. Biol. 7: 2378-2387, 1987). TGF- $\beta$  is biologically active as a disulfide-bonded dimer (Assoian et al., J. Biol. Chem. 258: 7155-7160, 1983). Factor XIII is a plasma protein that exists as a two chain homodimer in its activated form (Ichinose et al., Biochem. 25: 6900-

6906, 1986). PDGF, as noted above, is a disulfide-bonded, two chain molecule (Murray et al., U.S. Patent 4,766,073).

The present invention provides methods by which receptor analogs, including receptor analogs and PDGF-R 5 analogs, requiring dimerization for activity may be secreted from host cells. The methods described herein are particularly advantageous in that they allow the production of large quantities of purified receptors. The receptors may be used in assays for the screening of 10 potential ligands, in assays for binding studies, as imaging agents, and as agonists and antagonists within therapeutic agents.

A DNA sequence encoding a human PDGF receptor may be isolated as a cDNA using techniques known in the 15 art (see, for example, Okayama and Berg, Mol. Cell. Biol. 2: 161-170, 1982; Mol. Cell. Biol. 3: 280-289, 1983) from a library of human genomic or cDNA sequences. Such libraries may be prepared by standard procedures, such as those disclosed by Gubler and Hoffman (Gene 25: 263-269, 20 1983). It is preferred that the molecule is a cDNA molecule because cDNA lack introns and are therefore more suited to manipulation and expression in transfected or transformed cells. Sources of mRNA for use in the preparation of a cDNA library include the MG-63 human 25 osteosarcoma cell line (available from ATCC under accession number CRL 1427), diploid human dermal fibroblasts and human embryo fibroblast and brain cells (Matsui et al., *ibid.*). A cDNA encoding a PDGF $\beta$ -R has been cloned from a diploid human dermal fibroblast cDNA 30 library using oligonucleotide probes complementary to sequences of the mouse PDGF receptor (Gronwald et al., *ibid.*). A PDGF $\alpha$ -R cDNA has been isolated by Matsui et al. (*ibid.*) from human embryo fibroblast and brain cells. Alternatively, a cDNA encoding a PDGF $\alpha$ -R may be isolated 35 from a library prepared from MG-63 human osteosarcoma cells using a cDNA probe containing sequences encoding the transmembrane and cytoplasmic domains of the PDGF $\beta$ -R

(described by Kelly and Murray, *ibid.*). Partial cDNA clones (fragments) can be extended by re-screening of the library with the cloned cDNA fragment until the full sequence is obtained. In one embodiment, a ligand-binding

5 domain of a PDGF receptor is encoded by the sequence of ~~Figure 1B~~ <sup>Figure 1A-1G</sup> (Sequence ID Number 1) from amino acid 29 through amino acid 441. In another embodiment, a ligand-binding domain of a PDGF receptor is encoded by the sequence of ~~Figure 1B~~ <sup>Figure 1A-1G</sup> (Sequence ID Number 1) from amino acid 29 through amino acid 531. In yet another embodiment, a ligand-binding domain of a PDGF receptor is encoded by the sequence of ~~Figure 1B~~ <sup>Figure 1A-1D</sup> (Sequence ID Numbers 35 and 36) from amino acid 24 through amino acid 524. One skilled in the art may envision the use of a smaller DNA sequence encoding 15 the ligand-binding domain of a PDGF receptor containing at least 400 amino acids of the extracellular domain.

DNA sequences encoding EGF-R (Ullrich et al., *Nature* 304: 418-425, 1984), the insulin receptor (Ullrich et al., *Nature* 313: 756-761, 1985), nerve growth factor 20 (Ullrich et al. *Nature* 303: 821-825, 1983), colony stimulating factor-1 (Rettenmier et al., *ibid.*), transforming growth factor  $\beta$  (Derynck et al., *Nature* 316: 701-705, 1985), PDGF (Murray et al., *ibid.*), and factor XIII (Ichinose et al., *ibid.*) may also be used within the 25 present invention.

To direct polypeptides requiring dimerization for biological activity or receptor analogs into the secretory pathway of the host cell, at least one secretory signal sequence is used in conjunction with the DNA 30 sequence of interest. Preferred secretory signals include the alpha factor signal sequence (pre-pro sequence) (Kurjan and Herkowitz, *Cell* 30: 933-943, 1982; Kurjan et al., U.S. Patent No. 4,546,082; Brake, EP 116,201, 1983), the PHO5 signal sequence (Beck et al., WO 86/00637), the 35 BAR1 secretory signal sequence (MacKay et al., U.S. Patent No. 4,613,572; MacKay, WO 87/002670), immunoglobulin  $V_H$  signal sequences (Loh et al., *Cell* 33: 85-93, 1983; Watson

Nuc. Acids. Res. 12: 5145-5164, 1984) and immunoglobulin V<sub>k</sub> signal sequences (Watson, ibid.). Particularly preferred signal sequences are the SUC2 signal sequence (Carlson et al., Mol. Cell. Biol. 3: 439-447, 1983) and 5 PDGF receptor signal sequences. Alternatively, secretory signal sequences may be synthesized according to the rules established, for example, by von Heinje (Eur. J. Biochem. 133: 17-21, 1983; J. Mol. Biol. 184: 99-105, 1985; Nuc. Acids. Res. 14: 4683-3690, 1986).

10 Secretory signal sequences may be used singly or may be combined. For example, a first secretory signal sequence may be used singly or combined with a sequence encoding the third domain of Barrier (described in co-pending commonly assigned U.S. Patent Application Serial 15 No. 07/104,316, which is incorporated by reference herein in its entirety). The third domain of Barrier may be positioned in proper reading frame 3' of the DNA sequence of interest or 5' to the DNA sequence and in proper reading frame with both the secretory signal sequence and 20 the DNA sequence of interest.

In one embodiment of the present invention, a sequence encoding a dimerizing protein is joined to a sequence encoding a polypeptide chain of a polypeptide dimer or a receptor analog, and this fused sequence is 25 joined in proper reading frame to a secretory signal sequence. As shown herein, the present invention utilizes such an arrangement to drive the association of the polypeptide or receptor analog to form a biologically active molecule upon secretion. Suitable dimerizing 30 proteins include the S. cerevisiae repressible acid phosphatase (Mizunaga et al., J. Biochem. (Tokyo) 103: 321-326, 1988), the S. cerevisiae type 1 killer preprotoxin (Sturley et al., EMBO J. 5: 3381-3390, 1986), the S. calsbergensis alpha galactosidase melibiase 35 (Sumner-Smith et al., Gene 36: 333-340, 1985), the S. cerevisiae invertase (Carlson et al., Mol. Cell. Biol. 3: 439-447, 1983), the Neurospora crassa ornithine

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decarboxylase (Digangi et al., J. Biol. Chem. **262**: 7889-7893, 1987), immunoglobulin heavy chain hinge regions (Takahashi et al., Cell **29**: 671-679, 1982), and other dimerizing immunoglobulin sequences. In a preferred embodiment, S. cerevisiae invertase is used to drive the association of polypeptides into dimers. Portions of dimerizing proteins, such as those mentioned above, may be used as dimerizing proteins where those portions are capable of associating as a dimer in a covalent or noncovalent manner. Such portions may be determined by, for example, altering a sequence encoding a dimerizing protein through in vitro mutagenesis to delete portions of the coding sequence. These deletion mutants may be expressed in the appropriate host to determine which portions retain the capability of associating as dimers. Portions of immunoglobulin gene sequences may be used to drive the association of non-immunoglobulin polypeptides. These portions correspond to discrete domains of immunoglobulins. Immunoglobulins comprise variable and constant regions, which in turn comprise discrete domains that show similarity in their three-dimensional conformations. These discrete domains correspond to immunoglobulin heavy chain constant region domain exons, immunoglobulin heavy chain variable region domain exons, immunoglobulin light chain variable region domain exons and immunoglobulin light chain constant region domain exons in immunoglobulin genes (Hood et al., in Immunology, The Benjamin/Cummings Publishing Company, Inc., Menlo Park, CA; Honjo et al., Cell **18**: 559-568, 1979; Takahashi et al., Cell **29**: 671-679, 1982; and Honjo, Ann. Rev. Immun. **1**:499-528, 1983)). Particularly preferred portions of immunoglobulin heavy chains include Fab and Fab' fragments. (An Fab fragment is a portion of an immunoglobulin heavy chain that includes a heavy chain variable region domain and a heavy chain constant region domain. An Fab' fragment is a portion of an immunoglobulin heavy chain that includes a heavy chain

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variable region domain, a heavy chain constant region domain and a heavy chain hinge region domain.)

It is preferred to use an immunoglobulin light chain constant region in association with at least one immunoglobulin heavy chain constant region domain. In another embodiment, an immunoglobulin light chain constant region is associated with at least one immunoglobulin heavy chain constant region domain joined to an immunoglobulin hinge region. In one set of embodiments, an immunoglobulin light chain constant region joined in frame with a polypeptide chain of a non-immunoglobulin polypeptide dimer or receptor analog and is associated with at least one heavy chain constant region. In a preferred set of embodiments a variable region is joined upstream of and in proper reading frame with at least one immunoglobulin heavy chain constant region. In another set of embodiments, an immunoglobulin heavy chain is joined in frame with a polypeptide chain of a non-immunoglobulin polypeptide dimer or receptor analog and is associated with an immunoglobulin light chain constant region. In yet another set of embodiments, a polypeptide chain of a non-immunoglobulin polypeptide dimer or receptor analog <sup>is joined</sup> to at least one immunoglobulin heavy chain constant region which is joined to an immunoglobulin hinge region and is associated with an immunoglobulin light chain constant region. In a preferred set of embodiments an immunoglobulin <sup>In a</sup> <sup>Variably</sup> variable region is joined upstream of and in proper reading frame with the immunoglobulin light chain constant region.

Immunoglobulin heavy chain constant region domains include  $C_{H1}$ ,  $C_{H2}$ ,  $C_{H3}$ , and  $C_{H4}$  of any class of immunoglobulin heavy chain including  $\gamma$ ,  $\alpha$ ,  $\epsilon$ ,  $\mu$ , and  $\delta$  classes (Honjo, ibid., 1983) A particularly preferred immunoglobulin heavy chain constant region domain is human  $C_{H1}$ . Immunoglobulin variable regions include  $V_H$ ,  $V_K$ , or  $V_\lambda$ .

DNA sequences encoding immunoglobulins may be cloned from a variety of genomic or cDNA libraries known in the art. The techniques for isolating such DNA sequences using probe-based methods are conventional 5 techniques and are well known to those skilled in the art. Probes for isolating such DNA sequences may be based on published DNA sequences (see, for example, Hieter et al., Cell 22: 197-207, 1980). Alternatively, the polymerase chain reaction (PCR) method disclosed by Mullis et al. 10 (U.S. Patent No. 4,683,195) and Mullis (U.S. Patent No. 4,683,202), incorporated herein by reference may be used. The choice of library and selection of probes for the isolation of such DNA sequences is within the level of ordinary skill in the art.

15 Host cells for use in practicing the present invention include eukaryotic cells capable of being transformed or transfected with exogenous DNA and grown in culture, such as cultured mammalian and fungal cells. Fungal cells, including species of yeast (e.g., 20 Saccharomyces spp., Schizosaccharomyces spp.), or filamentous fungi (e.g., Aspergillus spp., Neurospora spp.) may be used as host cells within the present invention. Strains of the yeast Saccharomyces cerevisiae are particularly preferred.

25 Expression units for use in the present invention will generally comprise the following elements, operably linked in a 5' to 3' orientation: a transcriptional promoter, a secretory signal sequence a DNA sequence encoding nonimmunoglobulin polypeptide 30 requiring dimerization for biological activity joined to a dimerizing protein and a transcriptional terminator. The selection of suitable promoters, signal sequences and terminators will be determined by the selected host cell and will be evident to one skilled in the art and are 35 discussed more specifically below.

Suitable yeast vectors for use in the present invention include YRp7 (Struhl et al., Proc. Natl. Acad.

Sci. USA 76: 1035-1039, 1978), YEp13 (Broach et al., Gene 8: 121-133, 1979), pJDB249 and pJDB219 (Beggs, Nature 275:104-108, 1978) and derivatives thereof. Such vectors will generally include a selectable marker, which may be 5 one of any number of genes that exhibit a dominant phenotype for which a phenotypic assay exists to enable transformants to be selected. Preferred selectable markers are those that complement host cell auxotrophy, provide antibiotic resistance or enable a cell to utilize 10 specific carbon sources, and include LEU2 (Broach et al. *ibid.*), URA3 (Botstein et al., Gene 8: 17, 1979), HIS3 (Struhl et al., *ibid.*) or POT1 (Kawasaki and Bell, EP 171,142). Other suitable selectable markers include the 15 CAT gene, which confers chloramphenicol resistance on yeast cells.

Preferred promoters for use in yeast include promoters from yeast glycolytic genes (Hitzeman et al., J. Biol. Chem. 255: 12073-12080, 1980; Alber and Kawasaki, J. Mol. Appl. Genet. 1: 419-434, 1982; Kawasaki, U.S. Patent 20. No. 4,599,311) or alcohol dehydrogenase genes (Young et al., in Genetic Engineering of Microorganisms for Chemicals, Hollaender et al., (eds.), p. 355, Plenum, New York, 1982; Ammerer, Meth. Enzymol. 101: 192-201, 1983). In this regard, particularly preferred promoters are the 25 TPI1 promoter (Kawasaki, U.S. Patent No. 4,599,311, 1986) and the ADH2-4<sup>C</sup> promoter (Russell et al., Nature 304: 652-654, 1983 and Irani and Kilgore, described in pending, commonly assigned U.S. Patent Application Serial No. 07/183,130, which is incorporated herein by reference). 30 The expression units may also include a transcriptional terminator. A preferred transcriptional terminator is the TPI1 terminator (Alber and Kawasaki, *ibid.*).

In addition to yeast, proteins of the present invention can be expressed in filamentous fungi, for 35 example, strains of the fungi Aspergillus (McKnight and Upshall, described in commonly assigned U.S. Patent 4,935,349, which is incorporated herein by reference).

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Examples of useful promoters include those derived from Aspergillus nidulans glycolytic genes, such as the ADH3 promoter (McKnight et al., EMBO J. 4: 2093-2099, 1985) and the tpiA promoter. An example of a suitable terminator is  
5 the ADH3 terminator (McKnight et al., ibid.). The expression units utilizing such components are cloned into vectors that are capable of insertion into the chromosomal DNA of Aspergillus.

Techniques for transforming fungi are well known  
10 in the literature, and have been described, for instance, by Beggs (ibid.), Hinnen et al. (Proc. Natl. Acad. Sci. USA 75: 1929-1933, 1978), Yelton et al., (Proc. Natl. Acad. Sci. USA 81: 1740-1747, 1984), and Russell (Nature 301: 167-169, 1983). The genotype of the host cell will  
15 generally contain a genetic defect that is complemented by the selectable marker present on the expression vector. Choice of a particular host and selectable marker is well within the level of ordinary skill in the art.

In a preferred embodiment, a Saccharomyces cerevisiae host cell that contains a genetic deficiency in a gene required for asparagine-linked glycosylation of glycoproteins is used. Preferably, the S. cerevisiae host cell contains a genetic deficiency in the MNN9 gene (described in pending, commonly assigned U.S. Patent  
25 Application Serial Nos. 116,095 and 189,547 which are incorporated by reference herein in their entirety). Most preferably, the S. cerevisiae host cell contains a disruption of the MNN9 gene. S. cerevisiae host cells having such defects may be prepared using standard  
30 techniques of mutation and selection. Ballou et al. (J. Biol. Chem. 255: 5986-5991, 1980) have described the isolation of mannoprotein biosynthesis mutants that are defective in genes which affect asparagine-linked glycosylation. Briefly, mutagenized S. cerevisiae cells  
35 were screened using fluoresceinated antibodies directed against the outer mannose chains present on wild-type yeast. Mutant cells that did not bind antibody were

further characterized and were found to be defective in the addition of asparagine-linked oligosaccharide moieties. To optimize production of the heterologous proteins, it is preferred that the host strain carries a 5 mutation, such as the S. cerevisiae pep4 mutation (Jones, Genetics 85: 23-33, 1977), which results in reduced proteolytic activity.

In addition to fungal cells, cultured mammalian cells may be used as host cells within the present 10 invention. Preferred cell lines are rodent myeloma cell lines, which include p3X63Ag8 (ATCC TIB 9), FO (ATCC CRL 1646), NS-1 (ATCC TIB 18) and 210-RCY-Ag1 (Galfre et al., Nature 277: 131, 1979). A particularly preferred rodent 15 myeloma cell line is SP2/0-Ag14 (ATCC CRL 1581). In addition, a number of other cell lines may be used within the present invention, including COS-1 (ATCC CRL 1650), BHK, p363.Ag.8.653 (ATCC CRL 1580) Rat Hep I (ATCC CRL 1600), Rat Hep II (ATCC CRL 1548), TCMK (ATCC CCL 139), Human lung (ATCC CCL 75.1), Human hepatoma (ATCC HTB-52), 20 Hep G2 (ATCC HB 8065), Mouse liver (ATCC CC 29.1), 293 (ATCC CRL 1573; Graham et al., J. Gen. Virol. 36: 59-72, 1977) and DUKX cells (Urlaub and Chasin, Proc. Natl. Acad. Sci USA 77: 4216-4220, 1980) A preferred BHK cell line is the tk<sup>-</sup>ts13 BHK cell line (Waechter and Baserga, Proc. Natl. Acad. Sci USA 79: 1106-1110, 1982). A preferred BHK 25 cell line is the tk<sup>-</sup>ts13 BHK cell line (Waechter and Baserga, Proc. Natl. Acad. Sci. USA 79: 1106-1110, 1982). A tk<sup>-</sup> BHK cell line is available from the American Type Culture Collection, Rockville, MD, under accession number 30 CRL 1632. A particularly preferred tk<sup>-</sup> BHK cell line is BHK 570 which is available from the American Type Culture Collection under accession number 10314.

Mammalian expression vectors for use in carrying 35 out the present invention will include a promoter capable of directing the transcription of a cloned gene or cDNA. Preferred promoters include viral promoters and cellular promoters. Preferred viral promoters include the major

late promoter from adenovirus 2 (Kaufman and Sharp, Mol. Cell. Biol. 2: 1304-13199, 1982) and the SV40 promoter (Subramani et al., Mol. Cell. Biol. 1: 854-864, 1981). Preferred cellular promoters include the mouse  
5 metallothionein 1 promoter (Palmiter et al., Science 222: 809-814, 1983) and a mouse  $V_k$  promoter (Grant et al., Nuc. Acids Res. 15: 5496, 1987). A particularly preferred promoter is a mouse  $V_H$  promoter (Loh et al., *ibid.*). Such expression vectors may also contain a set of RNA splice  
10 sites located downstream from the promoter and upstream from the DNA sequence encoding the peptide or protein of interest. Preferred RNA splice sites may be obtained from adenovirus and/or immunoglobulin genes. Also contained in the expression vectors is a polyadenylation signal located  
15 downstream of the coding sequence of interest. Polyadenylation signals include the early or late polyadenylation signals from SV40 (Kaufman and Sharp, *ibid.*), the polyadenylation signal from the adenovirus 5 E1B region and the human growth hormone gene terminator  
20 (DeNoto et al., Nuc. Acids Res. 9: 3719-3730, 1981). A particularly preferred polyadenylation signal is the  $V_H$  gene terminator (Loh et al., *ibid.*). The expression vectors may include a noncoding viral leader sequence, such as the adenovirus 2 tripartite leader, located  
25 between the promoter and the RNA splice sites. Preferred vectors may also include enhancer sequences, such as the SV40 enhancer and the mouse  $\mu$  enhancer (Gillies, Cell 33: 717-728, 1983). Expression vectors may also include sequences encoding the adenovirus VA RNAs.  
30 Cloned DNA sequences may be introduced into cultured mammalian cells by, for example, calcium phosphate-mediated transfection (Wigler et al., Cell 14: 725, 1978; Corsaro and Pearson, Somatic Cell Genetics 7: 603, 1981; Graham and Van der Eb, Virology 52: 456, 1973.)  
35 Other techniques for introducing cloned DNA sequences into mammalian cells, such as electroporation (Neumann et al., EMBO J. 1: 841-845, 1982), may also be used. In order to

identify cells that have integrated the cloned DNA, a selectable marker is generally introduced into the cells along with the gene or cDNA of interest. Preferred selectable markers for use in cultured mammalian cells 5 include genes that confer resistance to drugs, such as neomycin, hygromycin, and methotrexate. The selectable marker may be an amplifiable selectable marker. A preferred amplifiable selectable marker is the DHFR gene. A particularly preferred amplifiable marker is the DHFR<sup>r</sup> 10 cDNA (Simonsen and Levinson, Proc. Natl. Acad. Sci. USA 80: 2495-2499, 1983). Selectable markers are reviewed by Thilly (Mammalian Cell Technology, Butterworth Publishers, Stoneham, MA) and the choice of selectable markers is well within the level of ordinary skill in the art.

15 Selectable markers may be introduced into the cell on a separate plasmid at the same time as the gene of interest, or they may be introduced on the same plasmid. If on the same plasmid, the selectable marker and the gene of interest may be under the control of different 20 promoters or the same promoter, the latter arrangement producing a dicistronic message. Constructs of this type are known in the art (for example, Levinson and Simonsen, U.S. Patent No. 4,713,339). It may also be advantageous to add additional DNA, known as "carrier DNA" to the 25 mixture which is introduced into the cells.

Transfected mammalian cells are allowed to grow for a period of time, typically 1-2 days, to begin expressing the DNA sequence(s) of interest. Drug selection is then applied to select for growth of cells 30 that are expressing the selectable marker in a stable fashion. For cells that have been transfected with an amplifiable selectable marker the drug concentration may be increased in a stepwise manner to select for increased copy number of the cloned sequences, thereby increasing 35 expression levels.

Host cells containing DNA constructs of the present invention are grown in an appropriate growth

medium. As used herein, the term "appropriate growth medium" means a medium containing nutrients required for the growth of cells. Nutrients required for cell growth may include a carbon source, a nitrogen source, essential amino acids, vitamins, minerals and growth factors. The growth medium will generally select for cells containing the DNA construct by, for example, drug selection or deficiency in an essential nutrient which are complemented by the selectable marker on the DNA construct or co-transfected with the DNA construct. Yeast cells, for example, are preferably grown in a chemically defined medium, comprising a non-amino acid nitrogen source, inorganic salts, vitamins and essential amino acid supplements. The pH of the medium is preferably maintained at a pH greater than 2 and less than 8, preferably at pH 6.5. Methods for maintaining a stable pH include buffering and constant pH control, preferably through the addition of sodium hydroxide. Preferred buffering agents include succinic acid and Bis-Tris (Sigma Chemical Co., St. Louis, MO). Yeast cells having a defect in a gene required for asparagine-linked glycosylation are preferably grown in a medium containing an osmotic stabilizer. A preferred osmotic stabilizer is sorbitol supplemented into the medium at a concentration between 0.1 M and 1.5 M., preferably at 0.5 M or 1.0 M. Cultured mammalian cells are generally grown in commercially available serum-containing or serum-free media. Selection of a medium appropriate for the particular cell line used is within the level of ordinary skill in the art.

The culture medium from appropriately grown transformed or transfected host cells is separated from the cell material, and the presence of dimerized polypeptide fusions or secreted receptor analogs is demonstrated. A preferred method of detecting receptor analogs, for example, is by the binding of the receptors or portions of receptors to a receptor-specific antibody. An anti-receptor antibody may be a monoclonal or

polyclonal antibody raised against the receptor in question, for example, an anti-PDGF receptor monoclonal antibody may be used to assay for the presence of PDGF receptor analogs. Another antibody, which may be used for 5 detecting substance P-tagged peptides and proteins, is a commercially available rat anti-substance P monoclonal antibody which may be utilized to visualize peptides or proteins that are fused to the C-terminal amino acids of substance P. Ligand binding assays may also be used to 10 detect the presence of receptor analogs. In the case of PDGF receptor analogs, it is preferable to use fetal foreskin fibroblasts, which express PDGF receptors, to compete against the PDGF receptor analogs of the present invention for labeled PDGF and PDGF isoforms.

15 Assays for detection of secreted, biologically active peptide dimers and receptor analogs may include Western transfer, protein blot or colony filter. A Western transfer filter may be prepared using the method described by Towbin et al. (Proc. Natl. Acad. Sci. USA 76: 20 4350-4354, 1979). Briefly, samples are electrophoresed in a sodium dodecylsulfate polyacrylamide gel. The proteins in the gel are electrophoretically transferred to nitrocellulose paper. Protein blot filters may be prepared by filtering supernatant samples or concentrates 25 through nitrocellulose filters using, for example, a Minifold (Schleicher & Schuell, Keene, NH). Colony filters may be prepared by growing colonies on a nitrocellulose filter that has been laid across an appropriate growth medium. In this method, a solid medium 30 is preferred. The cells are allowed to grow on the filters for at least 12 hours. The cells are removed from the filters by washing with an appropriate buffer that does not remove the proteins bound to the filters. A preferred buffer comprises 25 mM Tris-base, 19 mM glycine, 35 pH 8.3, 20% methanol.

The dimerized polypeptide fusions and receptor analogs present on the Western transfer, protein blot or

colony filters may be visualized by specific antibody binding using methods known in the art. For example, Towbin et al. (*ibid.*) describe the visualization of proteins immobilized on nitrocellulose filters with a 5 specific antibody followed by a labeled second antibody, directed against the first antibody. Kits and reagents required for visualization are commercially available, for example, from Vector Laboratories, (Burlingame, CA), and Sigma Chemical Company (St. Louis, MO).

10 Secreted, biologically active dimerized polypeptide fusions and receptor analogs may be isolated from the medium of host cells grown under conditions that allow the secretion of the biologically active dimerized polypeptide fusions and receptor analogs. The cell 15 material is removed from the culture medium, and the biologically active dimerized polypeptide fusions and receptor analogs are isolated using isolation techniques known in the art. Suitable isolation techniques include precipitation and fractionation by a variety of 20 chromatographic methods, including gel filtration, ion exchange chromatography and immunoaffinity chromatography. A particularly preferred purification method is immunoaffinity chromatography using an antibody directed against the receptor analog or dimerized polypeptide 25 fusion. The antibody is preferably immobilized or attached to a solid support or substrate. A particularly preferred substrate is CNBr-activated Sepharose (Pharmacia LKB Technologies, Inc., Piscataway, NJ). By this method, the medium is combined with the antibody/substrate under 30 conditions that will allow binding to occur. The complex may be washed to remove unbound material, and the receptor analog or peptide dimer is released or eluted through the use of conditions unfavorable to complex formation. Particularly useful methods of elution include changes in 35 pH, wherein the immobilized antibody has a high affinity for the ligand at a first pH and a reduced affinity at a second (higher or lower) pH; changes in concentration of

certain chaotropic agents; or through the use of detergents.

The secreted PDGF receptor analogs of the present invention can be used within a variety of assays for detecting the presence of and/or screening for native PDGF, PDGF isoforms or PDGF-like molecules. These assays will typically involve combining PDGF receptor analogs, which may be bound to a solid substrate such as polymeric microtiter plate wells, with a biological sample under conditions that permit the formation of receptor/ligand complexes. Screening assays for the detection of PDGF, PDGF isoforms or PDGF-like molecules will typically involve combining soluble PDGF receptor analogs with a biological sample and incubating the mixture with a PDGF isoform or mixture of PDGF isoforms bound to a solid substrate such as polymeric microtiter plates, under conditions that permit the formation of receptor/ligand complexes. Detection may be achieved through the use of a label attached to the receptor or through the use of a labeled antibody which is reactive with the receptor. Alternatively, the labeled antibody may be reactive with the ligand. A wide variety of labels may be utilized, such as radionuclides, fluorophores, enzymes and luminescers. Complexes may also be detected visually, i.e., in immunoprecipitation assays, which do not require the use of a label.

Secreted PDGF receptor analogs of the present invention may also be labeled with a radioisotope or other imaging agent and used for in vivo diagnostic purposes. Preferred radioisotope imaging agents include iodine-125 and technetium-99, with technetium-99 being particularly preferred. Methods for producing protein-isotope conjugates are well known in the art, and are described by, for example, Eckelman et al. (U.S. Patent No. 4,652,440), Parker et al. (WO 87/05030) and Wilber et al. (EP 203,764). Alternatively, the secreted receptor analogs may be bound to spin label enhancers and used for

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magnetic resonance (MR) imaging. Suitable spin label enhancers include stable, sterically hindered, free radical compounds such as nitroxides. Methods for labeling ligands for MR imaging are disclosed by, for  
5 example, Coffman et al. (U.S. Patent No. 4,656,026). For administration, the labeled receptor analogs are combined with a pharmaceutically acceptable carrier or diluent, such as sterile saline or sterile water. Administration is preferably by bolus injection, preferably  
10 intravenously. These imaging agents are particularly useful in identifying the locations of atherosclerotic plaques, PDGF-producing tumors, and receptor-bound PDGF.

The secreted PDGF receptor analogs of the present invention may also be utilized within diagnostic  
15 kits. Briefly, the subject receptor analogs are preferably provided in a lyophilized form or immobilized onto the walls of a suitable container, either alone or in conjunction with antibodies capable of binding to native PDGF or selected PDGF isoform(s) or specific ligands. The  
20 antibodies, which may be conjugated to a label or unconjugated, are generally included in the kits with suitable buffers, such as phosphate, stabilizers, inert proteins or the like. Generally, these materials are present in less than about 5% weight based upon the amount  
25 of active receptor analog, and are usually present in an amount of at least about 0.001% weight. It may also be desirable to include an inert excipient to dilute the active ingredients. Such an excipient may be present from about 1% to 99% weight of the total composition. In  
30 addition, the kits will typically include other standard reagents, instructions and, depending upon the nature of the label involved, reactants that are required to produce a detectable product. Where an antibody capable of binding to the receptor or receptor/ligand complex is  
35 employed, this antibody will usually be provided in a separate vial. The antibody is typically conjugated to a label and formulated in an analogous manner with the

formulations briefly described above. The diagnostic kits, including the containers, may be produced and packaged using conventional kit manufacturing procedures.

As noted above, the secreted PDGF receptor analogs of the present invention may be utilized within methods for purifying PDGF from a variety of samples. Within a preferred method, the secreted PDGF receptor analogs are immobilized or attached to a substrate or support material, such as polymeric tubes, beads, polysaccharide particulates, polysaccharide-containing materials, polyacrylamide or other water insoluble polymeric materials. Methods for immobilization are well known in the art (Mosbach et al., U.S. Patent No. 4,415,665; Clarke et al., Meth. Enzymology 68: 436-442, 1979). A common method of immobilization is CNBr activation. Activated substrates are commercially available from a number of suppliers, including Pharmacia (Piscataway, NJ), Pierce Chemical Co. (Rockford, IL) and Bio-Rad Laboratories (Richmond, CA). A preferred substrate is CNBr-activated Sepharose (Pharmacia, Piscataway, NJ). Generally, the substrate/receptor analog complex will be in the form of a column. The sample is then combined with the immobilized receptor analog under conditions that allow binding to occur. The substrate with immobilized receptor analog is first equilibrated with a buffer solution of a composition in which the receptor analog has been previously found to bind its ligand. The sample, in the solution used for equilibration, is then applied to the substrate/receptor analog complex. Where the complex is in the form of a column, it is preferred that the sample be passed over the column two or more times to permit full binding of ligand to receptor analog. The complex is then washed with the same solution to elute unbound material. In addition, a second wash solution may be used to minimize nonspecific binding. The bound material may then be released or eluted through the use of conditions unfavorable to

complex formation. Particularly useful methods include changes in pH, wherein the immobilized receptor has a high affinity for PDGF at a first pH and reduced affinity at a second (higher or lower) pH; changes in concentration of 5 certain chaotropic agents; or through the use of detergents.

The secreted PDGF receptor analogs fused to dimerizing proteins of the present invention may be used in pharmaceutical compositions for topical or intravenous 10 application. The secreted PDGF receptor analogs of the present invention may be useful in the treatment of atherosclerosis by, for example, binding endogenous PDGF to prevent smooth muscle cell proliferation. The PDGF receptor analogs fused to dimerizing proteins are used in 15 combination with a physiologically acceptable carrier or diluent. Preferred carriers and diluents include saline and sterile water. Pharmaceutical compositions may also contain stabilizers and adjuvants. The resulting aqueous solutions may be packaged for use or filtered under 20 aseptic conditions and lyophilized, the lyophilized preparation being combined with a sterile aqueous solution prior to administration.

The following examples are offered by way of illustration and not by way of limitation.

25

#### EXAMPLES

Enzymes, including restriction enzymes, DNA polymerase I (Klenow fragment), T4 DNA polymerase, T4 DNA 30 ligase and T4 polynucleotide kinase, were obtained from New England Biolabs (Beverly, MA), GIBCO-BRL (Gaithersburg, MD) and Boerhinger-Mannheim Biochemicals (Indianapolis, IN) and were used as directed by the manufacturer or as described in Maniatis et al. (Molecular 35 Cloning: A Laboratory Manual, Cold Spring Harbor Laboratory, NY, 1982) and Sambrook et al. (Molecular

Cloning: A Laboratory Manual/Second Edition, Cold Spring Harbor Laboratory, NY, 1989).

Example 1

5

Cloning PDGF Receptor cDNAs

A. Cloning the PDGF  $\beta$ -Receptor

A cDNA encoding the PDGF  $\beta$ -receptor was cloned as follows. Complementary DNA (cDNA) libraries were prepared from poly(A) RNA from diploid human dermal fibroblast 10 cells, prepared by explant from a normal adult, essentially as described by Hagen et al. (Proc. Natl. Acad. Sci. USA 83: 2412-2416, 1986). Briefly, the poly(A) RNA was primed with oligo d(T) and cloned into  $\lambda$ gt11 using Eco RI linkers. The random primed library was screened 15 for the presence of human PDGF receptor cDNA's using three oligonucleotide probes complementary to sequences of the mouse PDGF receptor (Yarden et al., Nature 323: 226-232, 1986). Approximately one million phage from the random primed human fibroblast cell library were screened using 20 oligonucleotides ZC904, ZC905 and ZC906 (Table 1; Sequence ID Numbers 5, 6 and 7, respectively). Eight positive clones were identified and plaque purified. Two clones, designated RP41 and RP51, were selected for further analysis by restriction enzyme mapping and DNA sequence 25 analysis. RP51 was found to contain 356 bp of 5'-noncoding sequence, the ATG translation initiation codon and 738 bp of the amino terminal coding sequence. RP41 was found to overlap clone RP51 and contained 2649 bp encoding amino acids 43-925 of the  $\beta$ -receptor protein.

30

Table 1  
Oligonucleotide Sequences

ZC871 (Sequence ID Number 3)

35 5' CTC TCT TCC TCA GGT AAA TGA GTG CCA GGG CCG GCA AGC CCC CGC TCC 3'

40

## ZC872 (Sequence ID Number 4)

5' CCG GGG AGC GGG GGC TTG CCG GCC CTG GCA CTC ATT TAC CTG  
AGG AAG AGA GAG CT 3'

## 5 ZC904 (Sequence ID Number 5)

5' CAT GGG CAC GTA ATC TAT AGA TTC ATC CTT GCT CAT ATC CAT  
GTA 3'

## ZC905 (Sequence ID Number 6)

10 5' TCT TGC CAG GGC ACC TGG GAC ATC TGT TCC CAC ATC ACC GG  
3'

## ZC906 (Sequence ID Number 7)

5' AAG CTG TCC TCT GCT TCA GCC AGA GGT CCT GGG CAG CC 3'

15

## ZC1380 (Sequence ID Number 8)

5' CAT GGT GGA ATT CCT GCT GAT 3'

## ZC1447 (Sequence ID Number 9)

20 5' TG GTT GTG CAG AGC TGA GGA AGA GAT GGA 3'

## ZC1453 (Sequence ID Number 10)

5' AAT TCA TTA TGT TGT TGC AAG CCT TCT TGT TCC TGC TAG CTG  
GTT TCG CTG TTA A 3'

25

## ZC1454 (Sequence ID Number 11)

5' GAT CTT AAC AGC GAA ACC AGC TAG CAG GAA CAA GAA GGC TTG  
CAA CAA CAT AAT G 3'

30

## ZC1478 (Sequence ID Number 12)

5' ATC GCG AGC ATG CAG ATC TGA 3'

## ZC1479 (Sequence ID Number 13)

5' AGC TTC AGA TCT GCA TGC TGC CGA T 3'

35

## ZC1776 (Sequence ID Number 14)

H |

5' AGC TGA GCG CAA ATG TTG TGT CGA GTG CCC ACC GTG CCC AGC  
TTA GAA TTC T 3'

ZC1777 (Sequence ID Number 15)

5 5' CTA GAG AAT TCT AAG CTG GGC ACG GTG GGC ACT CGA CAC AAC  
ATT TGC GCT C 3'

— ZC1846 (Sequence ID Number 16)

5' GAT CGG CCA CTG TCG GTG CGC TGC ACG CTG CGC AAC GCT GTG  
10 GGC CAG GAC ACG CAG GAG GTC ATC GTG GTG CCA CAC TCC TTG  
CCC TTT AAG CA 3'

ZC1847 (Sequence ID Number 17)

5' AGC TTG CTT AAA GGG CAA GGA GTG TGG CAC CAC GAT GAC CTC  
15 CTG CGT GTC CTG GCC CAC AGC GTT GCG CAG CGT GCA GCG CAC  
CGA CAG TGG CC 3'

ZC1886 (Sequence ID Number 18)

5' CCA GTG CCA AGC TTG TCT AGA CTT ACC TTT AAA GGG CAA GGA  
20 G 3'

ZC1892 (Sequence ID Number 19)

5' AGC TTG AGC GT 3'

25 ZC1893 (Sequence ID Number 20)

5' CTA GAC GCT CA 3'

ZC1894 (Sequence ID Number 21)

5' AGC TTC CAG TTC TTC GGC CTC ATG TCA GTT CTT CGG CCT CAT  
30 GTG AT 3'

ZC1895 (Sequence ID Number 22)

5' CTA GAT CAC ATG AGG CCG AAG AAC TGA CAT GAG GCC GAA GAA  
CTG GA 3'

5' AAT TCG GAT CCA CCA TGG GCA CCA GCC ACC CGG CGT TCC TGG  
TGT TAG GCT GCC TGC TGA CCG GCC 3'

ZC2182 (Sequence ID Number 24)

5' TGA GCC TGA TCC TGT GCC AAC TGA GCC TGC CAT CGA TCC TGC  
CAA ACG AGA ACG AGA AGG TTG TGC AGC TA 3'

ZC2183 (Sequence ID Number 25)

5' AAT TTA GCT GCA CAA CCT TCT CGT TCT CGT TTG GCA GGA TCG  
10 ATG GCA GGC TCA GTT GGC ACA GGA TCA 3'

ZC2184 (Sequence ID Number 26)

5' GGC TCA GGC CGG TCA GCA GGC AGC CTA ACA CCA GGA ACG CCG  
GGT GGC TGG TGC CCA TGG TGG ATC CG 3'

15

ZC2311 (Sequence ID Number 27)

5' TGA TCA CCA TGG CTC AAC TG 3'

ZC2351 (Sequence ID Number 28)

20 5' CGA ATT CCA C 3'

ZC2352 (Sequence ID Number 29)

5' CAT GGT GGA ATT CGA GCT 3'

25

ZC2392 (Sequence ID Number 30)

5' ACG TAA GCT TGT CTA GAC TTA CCT TCA GAA CGC AGG GTG GG  
3'

The 3'-end of the cDNA was not isolated in the  
30 first cloning and was subsequently isolated by screening  
 $6 \times 10^5$  phage of the oligo d(T)-primed cDNA library with a  
630 bp Sst I-Eco RI fragment derived from the 3'-end of  
clone RP41. One isolate, designated OT91, was further  
analyzed by restriction enzyme mapping and DNA sequencing.  
35 This clone was found to comprise the 3'-end of the  
receptor coding region and 1986 bp of 3' untranslated  
sequence.

Clones RP51, RP41 and OT91 were ligated together to construct a full-length cDNA encoding the entire PDGF  $\beta$ -receptor. RP41 was digested with Acc I and Bam HI to isolate the 2.12 kb fragment. RP51 was digested with Eco 5 RI and Acc I to isolate the 982 bp fragment. The 2.12 kb RP41 fragment and the 982 bp RP51 fragment were joined in a three-part ligation with pUC13, which had been linearized by digestion with Eco RI and Bam HI. The resultant plasmid was designated 51/41. Plasmid 51/41 was 10 digested with Eco RI and Bam HI to isolate the 3 kb fragment comprising the partial PDGF receptor cDNA. OT91 was digested with Bam HI and Xba I to isolate the 1.4 kb fragment containing the 3' portion of the PDGF receptor cDNA. The Eco RI-Bam HI 51/41 fragment, the Bam HI-Xba I 15 OT91 fragment and the Eco RI-Xba I digested pUC13 were joined in a three-part ligation. The resultant plasmid was designated pR-RX1 (Figure 2).

#### B. Cloning the PDGF- $\alpha$ Receptor

20 A cDNA encoding to PDGF  $\alpha$ -receptor was cloned as follows. RNA was prepared by the method of Chirgwin et al. (Biochemistry 18: 5294, 1979) and twice purified on oligo d(T) cellulose to yield poly(A)+ RNA. Complementary DNA was prepared in  $\lambda$ gt10 phage using a kit purchased from 25 Invitrogen (San Diego, CA). The resulting  $\lambda$  phage DNA was packaged with a coat particle mixture from Stratagene Cloning Systems (La Jolla, CA), infected into E. coli strain C600 Hfl<sup>-</sup> and titered.

30 Approximately  $1.4 \times 10^6$  phage recombinants were plated to produce plaques for screening. Nitrocellulose filter lifts were prepared according to standard methods and were hybridized to a radiolabeled PDGF  $\beta$ -receptor DNA fragment (Gronwald et al., ibid.) comprising the 1.9 kb Fsp I-Hind III fragment that encodes the transmembrane and 35 cytoplasmic domains of the PDGF  $\beta$ -receptor cDNA. Hybridization was performed for 36 hours at 42°C in a mixture containing 40% formamide, 5x SSCP (SSC containing

25 mM phosphate buffer, pH 6.5), 200 µg/ml denatured salmon sperm DNA, 3x Denhardt's, and 10% dextran sulfate. Following hybridization, the filters were washed extensively at room temperature in 2x SSC, then for 5 minutes at 47-48°C. Following an exposure to X-ray film, the filters were treated to increasingly stringent wash conditions followed by film recording until a final wash with 0.1x SSC at 65°C was reached. Film analysis showed that a "family" of plaques that hybridized at lower wash stringency but not at the highest stringency. This "family" was selected for further analysis.

Two λ phage clones from the "family" obtained from the initial screening were subcloned into the Not I site of the pUCtype plasmid vector pBluescript SK<sup>+</sup> (obtained from Stratagene Cloning Systems, La Jolla, CA) and were analyzed by restriction mapping and sequence analysis. Restriction enzyme analysis of a phage clone, designated α1-1, revealed a restriction fragment pattern dissimilar from that of the PDGF β-receptor cDNA with the exception of a common Bgl II-Bgl II band of approximately 160 bp. The PDGF β-receptor cDNA contains two similarly spaced Bgl II sites within the region coding for the second tyrosine kinase domain.

Restriction analysis of a second plasmid subclone (designated α1-7) revealed an overlap of the 5' approximately 1.2 kb of clone α1-1, and an additional approximately 2.2 kb of sequence extending in the 5' direction. Sequence analysis revealed that the 3' end of this clone encodes the second tyrosine kinase domain, which contains regions of near sequence identity to the corresponding regions in the PDGF β-receptor. The 5' end of clone α1-7 contained non-receptor sequences. Two additional α-receptor clones were obtained by probing with α1-1 sequences. Clone α1-1 was digested with Not I and Spe I, and a 230 bp fragment was recovered. Clone α1-1 was also digested with Bam HI and Not I, and a 550 bp fragment was recovered. A clone that hybridized to the 230 bp

probe was designated  $\alpha$ 5-1. This clone contained the 5'-most coding sequence for the PDGF  $\alpha$ -receptor. Another clone, designated  $\alpha$ 6-3, hybridized to the 550 bp probe and was found to contain 3' coding and non-coding sequences,  
5 including the poly(A) tail.

Clone  $\alpha$ 1-1 was radiolabeled ( $^{32}$ P) and used to probe a northern blot (Thomas, Methods Enzymol. **100**: 225-265, 1983) of the MG-63 poly(A)+ RNA used to prepare the cDNA library. A single band of approximately 6.6 kb was  
10 observed. RNA prepared from receptor-positive cell lines including the human fibroblast SK4, WI-38 and 7573 cell lines; the mouse fibroblast line DI 3T3; the U2-OS human osteosarcoma cell line and baboon aortic smooth muscle cells, and RNA prepared from receptor-negative lines  
15 including A431 (an epithelial cell line) and VA 13 (SV40-transformed WI-38 cells) were probed by northern format with the  $\alpha$ 1-1 cDNA. In all cases, the amount of the 6.6 kb band detected in these RNA correlated well with the relative levels of  $\alpha$ -receptor detected on the respective  
20 cell surfaces. The 6.6 kb RNA was not detected in RNA prepared from any tested cell line of hematopoietic origin, in agreement with a lack of PDGF  $\alpha$ -receptor protein detected on these cell types.

Clones  $\alpha$ 1-1 and  $\alpha$ 1-7 were joined at a unique  
25 Pst I site in the region encoding the transmembrane portion of the receptor. Clone  $\alpha$ 1-1 was digested with Xba I and Pst I and the receptor sequence fragment was recovered. Clone  $\alpha$ 1-7 was digested with Pst I and Bam HI and the receptor fragment was recovered. The two  
30 fragments were ligated with Xba I + Bam HI-digested pIC19R (Marsh et al. Gene **32**: 481-486, 1984) to construct plasmid p $\alpha$ 17R (Figure 12).

The remainder of the 5'-most  $\alpha$ -receptor sequence was obtained from clone  $\alpha$ 5-1 as an Sst I-Cla I fragment.  
35 This fragment was joined to the Eco RI-Sst I receptor fragment of p $\alpha$ 17R and cloned into Eco RI + Cla I-digested pBluescript SK+ plasmid to construct plasmid p $\alpha$ 17B (Figure

*FIGURES 11A-11D*  
 12). Figure 11 (Sequence ID Numbers 35 and 36) shows the nucleotide sequence and deduced amino acid sequence of the cDNA present in p<sub>a17B</sub>.

5

Example 2

Construction of a SUC2 Signal Sequence-PDGF  $\beta$ -Receptor Fusion

To direct the PDGF  $\beta$ -receptor into the yeast secretory pathway, the PDGF  $\beta$ -receptor cDNA was joined to a sequence encoding the Saccharomyces cerevisiae SUC2 signal sequence. Oligonucleotides ZC1453 and ZC1454 (Sequence ID Numbers 10 and 11; Table 1) were designed to form an adapter encoding the SUC2 secretory signal flanked by a 5' Eco RI adhesive end and a 3' Bgl II adhesive end. ZC1453 and ZC1454 were annealed under conditions described by Maniatis et al. (*ibid.*). Plasmid pR-RX1 was digested with Bgl II and Sst II to isolate the 1.7 kb fragment comprising the PDGF  $\beta$ -receptor coding sequence from amino acids 28 to 596. Plasmid pR-RX1 was also cut with Sst II and Hind III to isolate the 1.7 kb fragment comprising the coding sequence from amino acids 597 through the translation termination codon and 124 bp of 3' untranslated DNA. The two 1.7 kb pR-RX1 fragments and the ZC1453/ZC1454 adapter were joined with pUC19, which had been linearized by digestion with Eco RI and Hind III. The resultant plasmid, comprising the SUC2 signal sequence fused in-frame with the PDGF  $\beta$ -receptor cDNA, was designated pBTL10 (Figure 2).

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Example 3

Construction of pCBS22

The BAR1 gene product, Barrier, is an exported protein that has been shown to have three domains. When used in conjunction with a first signal sequence, the third domain of Barrier protein has been shown to aid in

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the secretion of proteins into the medium (MacKay et al., U.S. Patent Application Serial No. 104,316).

The portion of the BAR1 gene encoding the third domain of Barrier was joined to a sequence encoding the C-terminal portion of substance P (subP; Munro and Pelham, EMBO J. 3: 3087-3093, 1984). The presence of the substance P amino acids on the terminus of the fusion protein allowed the protein to be detected using commercially available anti-substance P antibodies.

10 Plasmid pZV9 (deposited as a transformant in E. coli strain RR1, ATCC accession no. 53283), comprising the entire BAR1 coding region and its associated flanking regions, was cut with Sal I and Bam HI to isolate the 1.3 kb BAR1 fragment. This fragment was subcloned into pUC13,

15 which had been cut with Sal I and Bam HI, to generate the plasmid designated pZV17. Plasmid pZV17 was digested with Eco RI to remove the 3'-most 0.5 kb of the BAR1 coding region. The vector-BAR1 fragment was religated to create the plasmid designated pJH66 (Figure 3). Plasmid pJH66

20 was linearized with Eco RI and blunt-ended with DNA polymerase I (Klenow fragment). Kinased Bam HI linkers (5' CCG GAT CCG G 3') were added and excess linkers were removed by digestion with Bam HI before religation. The resultant plasmid was designated pSW8 (Figure 3).

25 Plasmid pSW81, comprising the TPI1 promoter, the BAR1 coding region fused to the coding region of the C-terminal portion of substance P (Munro and Pelham, EMBO J. 3: 3087-3093, 1984) and the TPI1 terminator, was derived from pSW8. Plasmid pSW8 was cut with Sal I and Bam HI to

30 isolate the 824 bp fragment encoding amino acids 252 through 526 of BAR1. Plasmid pPM2, containing the synthetic oligonucleotide sequence encoding the dimer form of the C-terminal portion of substance P (subP) in M13mp8, was obtained from Hugh Pelham (MRC Laboratory of Molecular

35 Biology, Cambridge, England). Plasmid pPM2 was linearized by digestion with Bam HI and Sal I and ligated with the 824 bp BAR1 fragment from pSW8. The resultant plasmid,

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pSW14, was digested with Sal I and Sma I to isolate the 871 bp BAR1-substance P fragment. Plasmid pSW16, comprising a fragment of BAR1 encoding amino acids 1 through 250, was cut with Xba I and Sal I to isolate the 5 767 bp BAR1 fragment. This fragment was ligated with the 871 bp BAR1-substance P fragment in a three-part ligation with pUC18 cut with Xba I and Sma I. The resultant plasmid, designated pSW15, was digested with Xba I and Sma I to isolate the 1.64 kb BAR1-substance P fragment. The 10 ADH1 promoter was obtained from pRL029. Plasmid pRL029, comprising the ADH1 promoter and the BAR1 5' region encoding amino acids 1 to 33 in pUC18, was digested with Sph I and Xba I to isolate the 0.42 kb ADH1 promoter fragment. The TPI1 terminator (Alber and Kawasaki, *ibid.*) 15 was provided as a linearized fragment containing the TPI1 terminator and pUC18 with a Klenow-filled Xba I end and an Sph I end. This fragment was ligated with the 0.42 kb ADH1 promoter fragment and the 1.64 kb BAR1-substance P fragment in a three-part ligation to produce plasmid 20 pSW22.

The ADH1 promoter and the coding region of BAR1, from the translation initiation ATG through the Eco RV site present in pSW22, were removed by digestion with Hind III and Eco RV. The 3.9 kb vector fragment, comprising 25 the 401 bp between the Eco RV and the Eco RI sites of the BAR1 gene fused to subP and the TPI1 terminator, was isolated by gel electrophoresis. Oligonucleotide ZC1478 (Sequence ID Number 12; Table 1) was kinased and annealed with oligonucleotide ZC1479 (Sequence ID Number 13; Table 30 1) using conditions described by Maniatis et al. (*ibid.*). The annealed oligonucleotides formed an adapter comprising a Hind III adhesive end and a polylinker encoding Bgl II, Sph I, Nru I and Eco RV restriction sites. The ZC1479/ZC1478 adapter was ligated with the gel-purified 35 pSW22 fragment. The resultant plasmid was designated pCBS22 (Figure 3).

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Example 4  
Construction of pBTL13

In order to enhance the secretion of the PDGF  $\beta$ -receptor and to facilitate the identification of the secreted protein, a sequence encoding the third domain of BAR1 fused to the C-terminal amino acids of substance P was fused in frame with the 5' 1240 bp of the PDGF  $\beta$ -receptor. Plasmid pBTL10 (Example 2) was digested with Sph I and Sst I to isolate the 4 kb fragment comprising the SUC2 signal sequence, a portion of the PDGF  $\beta$ -receptor cDNA and the pUC19 vector sequences. Plasmid pCBS22 was digested with Sph I and Sst I to isolate the 1.2 kb fragment comprising the BAR1-subP fusion and the TPI1 terminator. These two fragments were ligated, and the resultant plasmid was designated pBTL13 (Figure 4).

Example 5  
Construction of an Expression Vector Encoding the Entire  
20 PDGF  $\beta$ -Receptor

The entire PDGF  $\beta$ -receptor was directed into the secretory pathway by fusing a SUC2 signal sequence to the 5' end of the PDGF  $\beta$ -receptor coding sequence. This fusion was placed behind the TPI1 promoter and inserted into the vector YEp13 for expression in yeast.

The TPI1 promoter was obtained from plasmid pTPIC10 (Alber and Kawasaki, J. Mol. Appl. Genet. 1: 410-434, 1982), and plasmid pFATPOT (Kawasaki and Bell, EP 30 171,142; ATCC 20699). Plasmid pTPIC10 was cut at the unique Kpn I site, the TPI1 coding region was removed with Bal-31 exonuclease, and an Eco RI linker (sequence: GGA ATT CC) was added to the 3' end of the promoter. Digestion with Bgl II and Eco RI yielded a TPI1 promoter 35 fragment having Bgl II and Eco RI sticky ends. This fragment was then joined to plasmid YRp7' (Stinchcomb et al., Nature 282: 39-43, 1979) that had been cut with Bgl

II and Eco RI (partial). The resulting plasmid, TE32, was cleaved with Eco RI (partial) and Bam HI to remove a portion of the tetracycline resistance gene. The linearized plasmid was then recircularized by the addition  
5 of an Eco RI-Bam HI linker to produce plasmid TEA32. Plasmid TEA32 was digested with Bgl II and Eco RI, and the 900 bp partial TPI1 promoter fragment was gel-purified. Plasmid pIC19H (Marsh et al., Gene 32:481-486, 1984) was cut with Bgl II and Eco RI and the vector fragment was gel  
10 purified. The TPI1 promoter fragment was then ligated to the linearized pIC19H and the mixture was used to transform E. coli RR1. Plasmid DNA was prepared and screened for the presence of a ~900 bp Bgl II-Eco RI fragment. A correct plasmid was selected and designated  
15 pICTPIP.

The TPI1 promoter was then subcloned to place convenient restriction sites at its ends. Plasmid pIC7 (Marsh et al., ibid.) was digested with Eco RI, the fragment ends were blunted with DNA polymerase I (Klenow fragment), and the linear DNA was recircularized using T4 DNA ligase. The resulting plasmid was used to transform E. coli RR1. Plasmid DNA was prepared from the transformants and was screened for the loss of the Eco RI site. A plasmid having the correct restriction pattern  
20 was designated pIC7RI\*. Plasmid pIC7RI\* was digested with Hind III and Nar I, and the 2500 bp fragment was gel-purified. The partial TPI1 promoter fragment (ca. 900 bp) was removed from pICTPIP using Nar I and Sph I and was gel-purified. The remainder of the TPI1 promoter was  
25 obtained from plasmid pFATPOT by digesting the plasmid with Sph I and Hind III, and a 1750 bp fragment, which included a portion of the TPI1 promoter fragment from pICTPIP, and the fragment from pFATPOT were then combined in a triple ligation to produce pMVR1 (Figure 2).

30 The TPI1 promoter was then joined to the SUC2-PDGF  $\beta$ -receptor fusion. Plasmid pBTL10 (Example 2) was digested with Eco RI and Hind III to isolate the 3.4 kb

fragment comprising the SUC2 signal sequence and the entire PDGF  $\beta$ -receptor coding region. Plasmid pMVR1 was digested with Bgl II and Eco RI to isolate the 0.9 kb TPI1 promoter fragment. The TPI1 promoter fragment and the 5 fragment derived from pBTL10 were joined with YEpl3, which had been linearized by digestion with Bam HI and Hind III, in a three-part ligation. The resultant plasmid was designated pBTL12 (Figure 2).

10

Example 6

**Construction of an Expression Vector Encoding the 5' Extracellular Portion of the PDGF  $\beta$ -Receptor**

The extracellular portion of the PDGF  $\beta$ -receptor 15 was directed into the secretory pathway by fusing the coding sequence to the SUC2 signal sequence. This fusion was placed in an expression vector behind the TPI1 promoter. Plasmid pBTL10 (Example 2) was digested with Eco RI and Sph I to isolate the approximately 1.3 kb 20 fragment comprising the SUC2 signal sequence and the PDGF  $\beta$ -receptor extracellular domain coding sequence. Plasmid pMVR1 (Example 5) was digested with Bgl II and Eco RI to isolate the 0.9 kb TPI1 promoter fragment. The TPI1 promoter fragment was joined with the fragment derived 25 from pBTL10 and YEpl3, which had been linearized by digestion with Bam HI and Sph I, in a three-part ligation. The resultant plasmid was designated pBTL11 (Figure 2).

Example 7

30 **Construction of Yeast Expression Vectors pBTL14 and pBTL15, and The Expression of PDGF  $\beta$ -Receptor-BAR1-subP Fusions**

**A. Construction of pBTL14**

35 The SUC2-PDGF $\beta$ -R fusion was joined with the third domain of BAR1 to enhance the secretion of the receptor, and the expression unit was cloned into a

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derivative of YEpl3 termed pJH50. YEpl3 was modified to destroy the Sal I site near the LEU2 gene. This was achieved by partially digesting YEpl3 with Sal I followed by a complete digestion with Xho I. The 2.0 kb Xho I-Sal  
5 I fragment comprising the LEU2 gene and the 8.0 kb linear YEpl3 vector fragment were isolated and ligated together. The ligation mixture was transformed into E. coli strain RR1. — DNA was prepared from the transformants and was analyzed by digestion with Sal I and Xho I. A clone was  
10 isolated which showed a single Sal I site and an inactive Xho I site indicating that the LEU2 fragment had inserted in the opposite orientation relative to the parent plasmid YEpl3. The plasmid was designated pJH50.

Referring to Figure 4, plasmid pBTL12 (Example 15 5) was digested with Sal I and Pst I to isolate the 2.15 kb fragment comprising 270 bp of YEpl3 vector sequence, the TPI1 promoter, the SUC2 signal sequence, and 927 bp of PDGF  $\beta$ -receptor cDNA. Plasmid pBTL13 (Example 4) was digested with Pst I and Hind III to isolate the 1.48 kb  
20 fragment comprising 313 bp of PDGF  $\beta$ -receptor cDNA, the BAR1-subP fusion and the TPI1 terminator. The fragments derived from pBTL12 and pBTL13 were joined with pJH50, which had been linearized by digestion with Hind III and Sal I, in a three-part ligation. The resultant plasmid  
25 was designated pBTL14.

#### B. Construction of pBTL15

Referring to Figure 5, a yeast expression vector was constructed comprising the TPI1 promoter, the SUC2 30 signal sequence, 1.45 kb of PDGF  $\beta$ -receptor cDNA sequence fused to the BAR1-subP fusion and the TPI1 terminator. Plasmid pBTL12 (Example 5) was digested with Sal I and Fsp I to isolate the 2.7 kb fragment comprising the TPI1 promoter, the SUC2 signal sequence, the PDGF $\beta$ -R coding  
35 sequence, and 270 bp of YEpl3 vector sequence. Plasmid pBTL13 (Example 4) was digested with Nru I and Hind III to isolate the 1.4 kb fragment comprising the BAR1-subP

fusion, the TPII terminator and 209 bp of 3' PDGF  $\beta$ -receptor cDNA sequence. The fragments derived from pBTL12 and pBTL13 were joined in a three-part ligation with pJH50, which had been linearized by digestion with Hind 5 III and Sal I. The resultant plasmid was designated pBTL15.

C. Expression of PDGF $\beta$ -R-subP fusions from pBTL14 and pBTL15

10 Yeast expression vectors pBTL14 and pBTL15 were transformed into Saccharomyces cerevisiae strains ZY100 (MATA leu2-3,112 ade2-101 suc2-Δ9 gal2 pep4::TPIIprom-CAT) and ZY400 (MATA leu2-3,112 ade2-101 suc2-Δ9 gal2 pep4::TPIIprom-CAT Amnn9::URA3). Transformations were 15 carried out using the method essentially described by Beggs (ibid.). Transformants were selected for their ability to grow on -LEUDS (Table 2).

20 Table 2  
Media Recipes

*T,05407*

-LeuThrTrp Amino Acid Mixture

4 g	adenine
3 g	L-arginine
25 5 g	L-aspartic acid
2 g	L-histidine free base
6 g	L-isoleucine
4 g	L-lysine-mono hydrochloride
2 g	L-methionine
30 6 g	L-phenylalanine
5 g	L-serine
5 g	L-tyrosine
4 g	uracil
6 g	L-valine

35 Mix all the ingredients and grind with a mortar and pestle until the mixture is finely ground.

-LEUDS

20 g glucose  
 6.7 g Yeast Nitrogen Base without amino acids (DIFCO  
 5 Laboratories Detroit, MI)  
 0.6 g -LeuThrTrp Amino Acid Mixture  
 182.2 g sorbitol  
 18 g Agar

10 Mix all the ingredients in distilled water. Add distilled water to a final volume of 1 liter. Autoclave 15 minutes. After autoclaving add 150 mg L-threonine and 40 mg L-tryptophan. Pour plates and allow to solidify.

15 -LEUDS + sodium succinate, pH 6.5

20 g Yeast Nitrogen Base without amino acids  
 0.6 g -LeuTrpThr Amino Acid Mixture  
 182.2 g sorbitol  
 11.8 g succinic acid

20 Mix all ingredients in distilled water to a final volume of 1 liter. Adjust the pH of the solution to pH 6.5. Autoclave 15 minutes. After autoclaving add 150 mg L-threonine and 40 mg L-tryptophan.

25

Fermentation Medium

7 g/l yeast nitrogen base without amino acids or ammonium sulfate (DIFCO Laboratories)  
 0.6 g/l ammonium sulfate  
 30 0.5 M sorbitol  
 0.39 g/l adenine sulfate  
 0.01% polypropylene glycol

Mix all ingredients in distilled water.  
 35 Autoclave 15 minutes. Add 80 ml 50% glucose for each liter of medium.

55

Super Synthetic -LEUD, pH 6.5 (liquid or solid medium)

- 6.7 g Yeast Nitrogen Base without amino acids or ammonium sulfate (DIFCO)  
 6 g ammonium sulfate  
 5 160 g adenine  
 0.6 g -LeuThrTrp Amino Acid Mixture  
 20 g glucose  
 11.8g succinic acid
- 10 Mix all ingredients and add distilled water to a final volume of 800 ml. Adjust the pH of the solution to pH 6.4. Autoclave 15 minutes. For solid medium, add 18 g agar before autoclaving, autoclave and pour plates.

15 Super Synthetic-LEUDS, pH 6.4 (liquid or solid medium)

Use the same recipe as Super Synthetic -LEUD, pH 6.4, but add 182.2 g sorbitol before autoclaving.

YEPD

- 20 20 g glucose  
 20 g Bacto Peptone (DIFCO Laboratories)  
 10 g Bacto Yeast Extract (DIFCO Laboratories)  
 18 g agar  
 4 ml adenine 1%  
 25 8 ml 1% L-leucine

Mix all ingredients in distilled water, and bring to a final volume of 1 liter. Autoclave 25 minutes and pour plates.

30

The transformants were assayed for binding to an anti-PDGF  $\beta$ -receptor monoclonal antibody (PR7212) or an anti-substance P antibody by protein blot assay.

- 35 ZY100[pBTL14] and ZY100[pBTL15] transformants were grown overnight at 30°C in 5 ml Super Synthetic -LEUD, pH 6.4 (Table 2). ZY400[pBTL14] and ZY400[pBTL15] transformants

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were grown overnight at 30°C in 5 ml Super Synthetic-LEUDS, pH 6.4 (Table 2). The cultures were pelleted by centrifugation and the supernatants were assayed for the presence of secreted PDGF  $\beta$ -receptor analogs by protein blot assay using methods described in Example 18. Results of assays using PR7212 are shown in Table 3.

*T10570+*  
10  
**TABLE 3**  
Results of a protein blot probed with PR7212

Transformant:	
ZY100[pBTL14]	+
ZY400[pBTL14]	++
ZY100[pBTL15]	+
15 ZY400[pBTL15]	+

Example 8

20 **Construction of a SUC2-PDGF $\beta$ -R Fusion Comprising the Complete PDGF $\beta$ -R Extracellular Domain**

A. Construction of pBTL22

The PDGF $\beta$ -R coding sequence present in pBTL10 was modified to delete the coding region 3' to the extracellular PDGF $\beta$ -R domain. As shown in Figure 6, 25 plasmid pBTL10 was digested with Sph I and Bam HI and with Sph I and Sst II to isolate the 4.77 kb fragment and the 466 bp fragment, respectively. The 466 bp fragment was then digested with Sau 3A to isolate the 0.17 kb fragment. The 0.17 kb fragment and the 4.77 kb were joined by 30 ligation. The resultant plasmid was designated pBTL21.

Plasmid pBTL21, containing a Bam HI site that was regenerated by the ligation of the Bam HI and Sau 3A sites, was digested with Hind III and Bam HI to isolate the 4.2 kb fragment. Synthetic oligonucleotides ZC1846 35 (Sequence ID Number 16; Table 1) and ZC1847 (Sequence ID Number 17; Table 1) were designed to form an adapter encoding the PDGF $\beta$ -R from the Sau 3A site after bp 1856

~~Figure 1B~~ Figure 1A-1G

(Sequence ID Number 1) to the end of the extracellular domain at 1958 bp (~~Sequence ID Number 1~~; Figure 1B, Sequence ID Number 1), having a 5' Bam HI adhesive end that destroys the Bam HI site and a 3' Hind III adhesive end.

- 5 Oligonucleotides ZC1846 and ZC1847 were annealed under conditions described by Maniatis et. al. (ibid.). The 4.2 pBTL21 fragment and the ZC1846/ZC1847 adapter were joined by ligation. The resultant plasmid, designated pBTL22, comprises the SUC2 signal sequence fused in proper reading  
 10 frame to the extracellular domain of PDGF $\beta$ -R in the vector pUC19 (Figure 6).

#### B. Construction of pBTL28

An in-frame translation stop codon was inserted  
 15 immediately after the coding region of the PDGF $\beta$ -R in pBTL22 using oligonucleotides ZC1892 (Sequence ID Number 19; Table 1) and ZC1893 (Sequence ID Number 20; Table 1). These oligonucleotides were designed to form an adapter encoding a stop codon in-frame with the PDGF $\beta$ -R coding  
 20 sequence from pBTL22 flanked by a 5' Hind III adhesive end and a 3' Xba I adhesive end. Plasmid pBTL22 was digested with Eco RI and Hind III to isolate the 1.6 kb SUC2-PDGF $\beta$ -R fragment. Plasmid pMVR1 was digested with Eco RI and Xba I to isolate the 3.68 kb fragment comprising the TPII  
 25 promoter, pIC7RI\* vector sequences and the TPII terminator. Oligonucleotides ZC1892 and ZC1893 were annealed to form a Hind III-Xba I adapter. The 1.6 kb SUC2-PDGF $\beta$ -R fragment, the 3.86 kb pMVR1 fragment and the ZC1892/ZC1893 adapter were joined in a three-part  
 30 ligation. The resultant plasmid was designated pBTL27.

The expression unit present in pBTL27 was inserted into the yeast expression vector pJH50 by first digesting pJH50 with Bam HI and Sal I to isolate the 10.3 kb vector fragment. Plasmid pBTL27 was digested with Bgl II and Eco RI and with Xho I and Eco RI to isolate the 0.9 kb TPII promoter fragment and the 1.65 kb fragment, respectively. The 10.3 kb pJH50 vector fragment, the 0.9

kb TPI1 promoter fragment and 1.65 kb fragment were joined in a three-part ligation. The resultant plasmid was designated pBTL28.

### 5 C. Construction of Plasmid pBTL30

The PDGF $\beta$ -R coding sequence present in plasmid pBTL22 was modified to encode the twelve C-terminal amino acids of substance P and an in-frame stop codon. Plasmid pBTL22 was digested with Eco RI and Hind III to isolate 10 the 1.6 kb SUC2-PDGF $\beta$ -R fragment. Plasmid pMVR1 was digested with Eco RI and Xba I to isolate the 3.68 kb fragment comprising the TPI1 promoter, pIC7RI\* and the TPI1 terminator. Synthetic oligonucleotides ZC1894 (Sequence ID Number 21; Table 1) and ZC1895 (Sequence ID 15 Number 22; Table 1) were annealed to form an adapter containing the codons for the twelve C-terminal amino acids of substance P followed by an in-frame stop codon and flanked on the 5' end with a Hind III adhesive end and on the 3' end with an Xba I adhesive end. The 20 ZC1894/ZC1895 adapter, the 1.6 kb SUC2-PDGF $\beta$ -R fragment and the pMVR1 fragment were joined in a three-part ligation. The resultant plasmid, designated pBTL29, was digested with Eco RI and Xho I to isolate the 1.69 kb 25 SUC2-PDGF $\beta$ -R-subP-TPI1 terminator fragment. Plasmid pBTL27 was digested with Bgl II and Eco RI to isolate the 0.9 kb TPI1 promoter fragment. Plasmid pJH50 was digested with Bam HI and Sal I to isolate the 10.3 kb vector fragment. The 1.69 kb pBTL29 fragment, the 0.9 kb TPI1 promoter fragment and the 10.3 kb vector fragment were 30 joined in a three-part ligation. The resulting plasmid was designated pBTL30.

### Example 9

#### Construction and Expression of a SUC2-PDGF $\beta$ -R-IgG Hinge 35 Expression Vector

An expression unit comprising the TPI1 promoter, the SUC2 signal sequence, the PDGF $\beta$ -R extracellular

domain, an immunoglobulin hinge region and the TPI1 terminator was constructed. Plasmid pBTL22 was digested with Eco RI and Hind III to isolate the 1.56 kb fragment. Plasmid pMVR1 was digested with Eco RI and Xba I to 5 isolate the 3.7 kb fragment, comprising the TPI1 promoter, pIC7RI\* vector sequences and the TPI1 terminator. Oligonucleotides ZC1776 (Sequence ID Number 14; Table 1) and ZC1777 (Sequence ID Number 15; Table 1) were designed to form, when annealed, an adapter encoding an 10 immunoglobulin hinge region with a 5' Hind III adhesive end and a 3' Xba I adhesive end. Oligonucleotides ZC1776 and ZC1777 were annealed under conditions described by Maniatis et al. (ibid.). The 1.56 kb pBTL22 fragment, the 3.7 kb fragment and the ZC1776/ZC1777 adapter were joined 15 in a three-part ligation, resulting in plasmid pBTL24.

The expression unit of pBTL24, comprising the TPI1 promoter, SUC2 signal sequence, PDGF $\beta$ -R extracellular domain sequence, hinge region sequence, and TPI1 terminator, was inserted into pJH50. Plasmid pBTL24 was 20 digested with Xho I and Hind III to isolate the 2.4 kb expression unit. Plasmid pJH50 was digested with Hind III and Sal I to isolate the 9.95 kb fragment. The 2.4 kb pBTL24 fragment and 9.95 kb pJH50 vector fragment were joined by ligation. The resultant plasmid was designated 25 pBTL25.

Plasmid pBTL25 was transformed into Saccharomyces cerevisiae strain ZY400 using the method essentially described by Beggs (ibid.). Transformants were selected for their ability to grow on -LEUDS (Table 30 2). The transformants were tested for their ability to bind the anti-PDGFB-R monoclonal antibody PR7212 using the colony assay method described in Example 18. Plasmid pBTL25 transformants were patched onto nitrocellulose filters that had been wetted and supported by YEPD solid 35 medium. Antibody PR7212 was found to bind to the PDGF $\beta$ -R-IgG hinge fusion secreted by ZY400[pBTL25] transformants.

60

Example 10

Construction and Expression of a SUC2 signal sequence-PDGF $\beta$ -R Extracellular Domain-SUC2 Fusion

As shown in Figure 6, an expression unit comprising the TPI1 promoter, SUC2 signal sequence, PDGF $\beta$ -R extracellular domain sequence, and SUC2 coding sequence was constructed as follows. Plasmid pBTL22 was digested with Eco RI and Hind III to isolate the 1.6 kb SUC2-PDGF $\beta$ -R fragment. Plasmid pMVR1 was digested with Bgl II and 5 Eco RI to isolate the 0.9 kb TPI1 promoter fragment. The SUC2 coding region was obtained from pJH40. Plasmid pJH40 was constructed by inserting the 2.0 kb Hind III-Hind III SUC2 fragment from pRB58 (Carlson et al., Cell 28:145-154, 10 1982) into the Hind III site of pUC19 followed by the destruction of the Hind III site 3' to the coding region. Plasmid pJH40 was digested with Hind III and Sal I to 15 isolate the 2.0 kb SUC2 coding sequence. Plasmid pJH50 was digested with Sal I and Bam HI to isolate the 10.3 kb vector fragment. The 0.9 kb Bgl II-Eco RI TPI1 promoter 20 fragment, the 1.6 kb Eco RI-Hind III SUC2-PDGF $\beta$ -R, the 2.0 kb Hind III-Sal I SUC2 fragment and the 10.3 kb Bam HI-Sal I vector fragment were joined in a four-part ligation. The resultant plasmid was designated pBTL26 (Figure 6).

Plasmid pBTL26 was transformed into 25 Saccharomyces cerevisiae strain ZY400 using the method essentially described by Beggs (*ibid.*). Transformants were selected for their ability to grow on -LEUDS (Table 2). ZY400 transformants (ZY400[pBTL26]) were assayed by protein blot (Example 18), colony blot (Example 18) and 30 competition assay.

Protein blot assays were carried out on ZY400[pBTL26] and ZY400[pJH50] (control) transformants that had been grown in flasks. Two hundred-fifty microliters of a 5 ml overnight cultures of ZY400[pBTL26] 35 and ZY400 [pJH50] in -LEUDS + sodium succinate, pH 6.5 (Table 2) were inoculated into 50 ml of -LEUDS + sodium succinate, pH 6.5. The cultures were incubated for 35

hours in an airbath shaker at 30°C. The culture supernatants were harvested by centrifugation. The culture supernatants were assayed as described in Example 18 and were found to bind PR7212 antibody.

5 Colony assays were carried out on ZY400[pBTL26] transformants. ZY400[pBTL26] transformants were patched onto wetted nitrocellulose filters that were supported on a YEPD plate. The colony assay carried out as described in Example 8.A. showed that ZY400[pBTL26] antibodies bound  
10 PR7212 antibodies.

Competition binding assays were carried out on ZY400[pBTL26] and ZY400[pJH50] transformants. The transformants were grown in two liters of fermentation medium (Table 2) in a New Brunswick Bioflo2 fermentor (New  
15 Brunswick, Philadelphia, PA) with continuous pH control at pH 6.4. The cultures were adjusted to pH 7.5 immediately prior to harvesting. Culture supernatants were concentrated in an Amicon concentrator (Amicon, San Francisco, CA) using an Amicon 10<sup>4</sup> mw spiral filter  
20 cartridge. The concentrated supernatants were further concentrated using Amicon Centriprep 10's. Fifteen milliliters of the concentrated supernatant samples were added to the Centripreps, and the Centripreps were spun in a Beckman GRP centrifuge (Beckman Instruments Inc.,  
25 Carlsbad, CA) at setting 5 for a total of 60 minutes. The concentrates were removed from the Centripreps and were assayed in the competition assay.

The competition binding assay measured the amount of <sup>125</sup>I-PDGF left to bind to fetal foreskin  
30 fibroblast cells after preincubation with the concentrate containing the PDGF $\beta$ -R-SUC2 fusion protein. PDGF-AA and PDGF-AB were iodinated using the Iodopead method (Pierce Chemical). PDGF-BB<sub>Tyr</sub> was iodinated and purified as described in Example 18.F. The concentrate was serially  
35 diluted in binding medium (Table 4). The dilutions were mixed with 0.5 ng of iodinated PDGF-AA, PDGF-BB<sub>Tyr</sub> or PDGF-AB, and the mixtures were incubated for two hours at  
*(cont)*

room temperature. Three hundred micrograms of unlabeled PDGF-BB was added to each sample mixture. The sample mixtures were added to 24-well plates containing confluent fetal foreskin fibroblast cells (AG1523, available from 5 the Human Genetic Mutant Cell Repository, Camden, NJ). The cells were incubated with the mixture for four hours at 4°C. The supernatants were aspirated from the wells, and the wells were rinsed three times with phosphate buffered saline that was held at 4°C (PBS; Sigma, St. 10 Louis, Mo.). Five hundred microliters of PBS + 1% NP-40 was added to each well, and the plates were shaken on a platform shaker for five minutes. The cells were harvested and the amount of iodinated PDGF was determined. 15 The results of the competition binding assay showed that the PDGF $\beta$ -R-SUC2 fusion protein was able to competitively bind all three isoforms of PDGF.

The PDGF $\beta$ -R produced from ZY400 [pBTL26] transformants was tested for cross reactivity to fibroblast growth factor (FGF) and transforming growth 20 factor- $\beta$  (TGF- $\beta$ ) using the competition assay essentially described above. Supernatant concentrates from ZY400[pBTL26] and ZY400[JH50] (control) transformants were serially diluted in binding medium (Table 4). The dilutions were mixed with 7.9 ng of iodinated FGF or 14 ng 25 of iodinated TGF- $\beta$ , and the mixtures were incubated for two hours at room temperature. Fourteen micrograms of unlabeled FGF was added to each mixture containing labeled FGF, and 7  $\mu$ g of unlabeled TGF- $\beta$  was added to each mixture containing labeled TGF- $\beta$ . The sample mixtures were added 30 to 24-well plates containing confluent human dermal fibroblast cells. (Human dermal fibroblast cells express both FGF receptors and TGF $\beta$  receptors.) The cells were incubated with the mixtures for four hours at 4°C. Five hundred microliters of PBS + 1% NP-40 was added to each 35 well, and the plates were shaken on a platform shaker for five minutes. The cells were harvested and the amount of iodinated FGF or TGF- $\beta$  bound to the cells was determined.

The results of these assays showed that the PDGF $\beta$ -R-SUC2 fusion protein did not cross react with FGF or TGF- $\beta$ .

Table 4  
5 Reagent Recipes

Binding Medium

500 ml Ham's F-12 medium  
 12 ml 1M HEPES, pH 7.4  
 10 5 ml 100x PSN (Penicillin/Streptomycin/Neomycin,  
 Gibco)  
 - 1 g rabbit serum albumin

Western Transfer Buffer

15 25 mM Tris, pH 8.3  
 19 mM glycine, pH 8.3  
 20% methanol

Western Buffer A

20 50 ml 1 M Tris, pH 7.4  
 20 ml 0.25 mM EDTA, pH 7.0  
 5 ml 10% NP-40  
 37.5 ml 4 M NaCl  
 2.5 g gelatin

25  
 The Tris, EDTA, NP-40 and NaCl were diluted to a final volume of one liter with distilled water. The gelatin was added to 300 ml of this solution and the solution was heated in a microwave until the gelatin was 30 in solution. The gelatin solution was added back to the remainder of the first solution and stirred at 4°C until cool. The buffer was stored at 4°C.

Western Buffer B

35 50 ml 1 M Tris, pH 7.4  
 20 ml 0.25 M EDTA, pH 7.0  
 5 ml 10% NP-40

58.4 g NaCl  
2.5 g gelatin  
4 g N-lauroyl sarcosine

- 5 The Tris, EDTA, NP-40, and the NaCl were mixed  
and diluted to a final volume of one liter. The gelatin  
was added to 300 ml of this solution and heated in a  
microwave until the gelatin was in solution. The gelatin  
solution was added back to the original solution and the  
10 N-lauroyl sarcosine was added. The final mixture was  
stirred at 4°C until the solids were completely dissolved.  
This buffer was stored at 4°C.

### 2x Loading Buffer

15 36 ml 0.5 M Tris-HCl, pH 6.8  
50 16 ml glycerol  
16 ml 20% SDS  
4 ml 0.5% Bromphenol Blue in 0.5 M Tris-HCl, pH 6.8

- 20 Mix all ingredients. Immediately before use,  
add 100  $\mu$ l  $\beta$ -mercaptoethanol to each 900  $\mu$ l dye mix

### Example 11

## **Construction and Expression of PDGF Receptor Analogs From BHK cells**

#### A. Construction of pBTL114 and pBTL115

The portions of the PDGF  $\beta$ -receptor extracellular domain present in pBTL14 and pBTL15 were placed in a mammalian expression vector. Plasmids pBTL14 and pBTL15 were digested with Eco RI to isolate the 1695 bp and 1905 bp SUC2 signal-PDGF $\beta$ -R-BAR1 fragments. The 1695 bp fragment and the 1905 bp fragment were each ligated to Zem229R that had been linearized by digestion with Eco RI.

The vector Zem229R was constructed as shown in Figure 10 from Zem229. Plasmid Zem229 is a pUC18-based

expression vector containing a unique Bam HI site for insertion of cloned DNA between the mouse metallothionein-1 promoter and SV40 transcription terminator and an expression unit containing the SV40 early promoter, mouse dihydrofolate reductase gene, and SV40 transcription terminator. Zem229 was modified to delete the Eco RI sites flanking the Bam HI cloning site and to replace the Bam HI site with a single Eco RI cloning site. The plasmid was partially digested with Eco RI, treated with DNA polymerase I (Klenow fragment) and dNTPs, and religated. Digestion of the plasmid with Bam HI followed by ligation of the linearized plasmid with a Bam HI-Eco I adapter resulted in a unique Eco RI cloning site. The resultant plasmid was designated Zem229R.

The ligation mixtures were transformed into E. coli strain RR1. Plasmid DNA was prepared and the plasmids were subjected to restriction enzyme analysis. A plasmid having the 1695 bp pBTL14 fragment inserted into Zem229R in the correct orientation was designated pBTL114 (Figure 9). A plasmid having the 1905 bp pBTL15 fragment inserted into Zem229R in the correct orientation was designated pBTL115 (Figure 9).

B. Expression of secreted PDGF  $\beta$ -receptor analogs in tk<sup>-</sup> ts13 BHK cells

Plasmids pBTL114 and pBTL115 were each transfected into tk<sup>-</sup>ts13 cells using calcium phosphate precipitation (essentially as described by Graham and van der Eb, J. Gen. Virol. 36: 59-72, 1977). The transfected cells were grown in Dulbecco's modified Eagle's medium (DMEM) containing 10% fetal calf serum, 1x PSN antibiotic mix (Gibco 600-5640), 2.0 mM L-glutamine. The cells were selected in 250 nM methotrexate (MTX) for 14 days, and the resulting colonies were screened by the immunofilter assay (McCracken and Brown, Biotechniques, 82-87, March/April 1984). Plates were rinsed with PBS or No Serum medium (DMEM plus 1x PSN antibiotic mix). Teflon® mesh (Spectrum

Medical Industries, Los Angeles, CA) was then placed over the cells. Nitrocellulose filters were wetted with PBS or No Serum medium, as appropriate, and placed over the mesh. After six hours incubation at 37°C, filters were removed 5 and placed in Wester buffer A (Table 4) overnight at room temperature. The filters were developed using the antibody PR7212 and the procedure described in Example 8. The filters showed that conditioned media from pBTL114-transfected and pBTL115-transfected BHK cells bound the 10 PR7212 antibody indicating the presence of biologically active secreted PDGF $\beta$ -R.

Example 12

Expression of PDGF  $\beta$ -Receptor Analogs in Cultured Mouse  
15 Myeloma Cells

A. Construction of pIC $\mu$ PRES

The immunoglobulin  $\mu$  heavy chain promoter and enhancer were subcloned into pIC19H to provide a unique 20 Hind III site 3' to the promoter. Plasmid p $\mu$  (Grosschedl and Baltimore, Cell 41: 885-897, 1985) was digested with Sal I and Eco RI to isolate the 3.1 kb fragment comprising the  $\mu$  promoter. Plasmid pIC19H was linearized by digestion with Eco RI and Xho I. The  $\mu$  promoter fragment 25 and the linearized pIC19H vector fragment were joined by ligation. The resultant plasmid, designated pIC $\mu$ 3, was digested with Ava II to isolate the 700 bp  $\mu$  promoter fragment. The 700 bp fragment was blunt-ended by treatment with DNA polymerase I (Klenow fragment) and 30 deoxynucleotide triphosphates. Plasmid pIC19H was linearized by digestion with Xho I, and the adhesive ends were filled in by treatment with DNA polymerase I (Klenow fragment) and deoxynucleotide triphosphates. The blunt-ended Ava II fragment was ligated with the blunt-ended, 35 linearized pIC19H, and the ligation mixture was transformed into E. coli JM83. Plasmid DNA was prepared from the transformants and was analyzed by restriction

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digest. A plasmid with a Bgl II site 5' to the promoter was designated pIC $\mu$ PR1(-). Plasmid pIC $\mu$ PR1(-) was digested with Hind III and Bgl II to isolate the 700 bp  $\mu$  promoter fragment. Plasmid pIC19R was linearized by digestion with 5 Hind III and Bam HI. The 700 bp promoter fragment was joined with the linearized pIC19R by ligation. The resultant plasmid, designated pIC $\mu$ PR7, comprised the  $\mu$  promoter with an unique Sma I site 5' to the promoter and a unique Hind III site 3' to the promoter.

10 The immunoglobulin heavy chain  $\mu$  enhancer (Gillies et al., Cell 33: 717-728, 1983) was inserted into the unique Sma I site to generate plasmid pIC $\mu$ PRES. Plasmid pJ4 (obtained from F. Blattner, Univ. Wisconsin, Madison, Wisconsin), comprising the 1.5 kb Hind III-Eco RI 15  $\mu$  enhancer fragment in the vector pAT153 (Amersham, Arlington Heights, IL), was digested with Hind III and Eco RI to isolate the 1.5 kb enhancer fragment. The adhesive ends of the enhancer fragment were filled in by treatment with T4 DNA polymerase and deoxynucleotide triphosphates.

20 The blunt-ended fragment and pIC $\mu$ PR7, which had been linearized by digestion with Sma I, were joined by ligation. The ligation mixture was transformed into E. coli RR1. Plasmid DNA was prepared from the transformants, and the plasmids were analyzed by 25 restriction digests. A plasmid comprising the  $\mu$  enhancer and the  $\mu$  promoter was designated pIC $\mu$ PRES (Figure 7).

#### B. Construction of pSDL114

The DNA sequence encoding the extracellular 30 domain of the PDGF  $\beta$ -receptor was joined with the DNA sequence encoding the human immunoglobulin light chain constant region. The PDGF  $\beta$ -receptor extracellular domain was obtained from mpBTL22, which comprised the Eco RI-Hind III fragment from pBTL22 (Example 8.A.) cloned into Eco 35 RI-Hind III cut M13mp18. Single stranded DNA was prepared from a mpBTL22 phage clone, and the DNA was subjected to in vitro mutagenesis using the oligonucleotide ZC1886

(Table 1) and the method described by Kunkel (Proc. Natl. Acad. Sci. USA 82: 488-492, 1985). A phage clone comprising the mutagenized PDGF $\beta$ -R with a donor splice site (5' splice site) at the 3' end of the PDGF $\beta$ -R extracellular domain was designated pBTLR-HX (Figure 7).

The native PDGF $\beta$ -R signal sequence was obtained from pPR5. Plasmid pPR5, comprising 738 bp of 5' coding sequence with an Eco RI site immediately 5' to the translation initiation codon, was constructed by *in vitro* mutagenesis of the PDGF $\beta$ -R cDNA fragment from RP51 (Example 1). Replicative form DNA of RP51 was digested with Eco RI to isolate the 1.09 kb PDGF $\beta$ -R fragment. The PDGF $\beta$ -R fragment was cloned into the Eco RI site of M13mp18. Single stranded template DNA was prepared from a phage clone containing the PDGF $\beta$ -R fragment in the proper orientation. The template DNA was subjected to *in vitro* mutagenesis using oligonucleotide ZC1380 (Sequence ID Number 8; Table 1) and the method described by Zoller and Smith (Meth. Enzymol. 100: 468-500, 1983). The mutagenesis resulted in the placement of an Eco RI site immediately 5' to the translation initiation codon. Mutagenized phage clones were analyzed by dideoxy sequence analysis. A phage clone containing the ZC1380 mutation was selected, and replicative form (Rf) DNA was prepared from the phage clone. The Rf DNA was digested with Eco RI and Acc I to isolate the 0.63 kb fragment. Plasmid pR-RXI (Example 1) was digested with Acc I and Eco RI to isolate the 3.7 kb fragment. The 0.63 kb fragment and the 3.7 kb fragment were joined by ligation resulting in plasmid pPR5 (Figure 7).

As shown in Figure 7, the PDGF $\beta$ -R signal peptide and part of the extracellular domain were obtained from plasmid pPR5 as a 1.4 kb Eco RI-Sph I fragment. Replicative form DNA from phage clone pBTLR-HX was digested with Sph I and Hind III to isolate the approximately 0.25 kb PDGF $\beta$ -R fragment. Plasmid pUC19 was linearized by digestion with Eco RI and Hind III. The 1.4

kb Eco RI-Sph I PDGF $\beta$ -R fragment, the 0.25 kb Sph I-Hind III fragment from pBTLR-HX and the Eco RI-Hind III cut pUC19 were joined in a three-part ligation. The resultant plasmid, pSDL110, was digested with Eco RI and Hind III to 5 isolate the 1.65 kb PDGF $\beta$ -R fragment.

Plasmid pICHuCK3.9.11 was used as the source of the human immunoglobulin light chain gene (Figure 7). The human immunoglobulin light chain gene was isolated from a human genomic library using an oligonucleotide probe (5' 10 TGT GAC ACT CTC CTG GGA GTT A 3'; Sequence ID Number 32), which was based on a published human kappa C gene sequence (Hieter et al., Cell 22: 197-207, 1980). The human light chain (kappa) constant region was subcloned as a 1.1 kb Sph I-Hinf I genomic fragment of the human kappa gene, 15 which has been treated with DNA polymerase DNA I (Klenow Fragment) to fill in the Hinf I adhesive end, into Sph I-Hinc II cut pUC19. The 1.1 kb human kappa constant region was subsequently isolated as a 1.1 kb Sph I-Bam HI fragment that was subcloned into Sph I-Bgl II cut pIC19R 20 (Marsh et al., *ibid.*). The resultant plasmid was designated pICHuCK3.9.11. Plasmid pICHuCK3.9.11 was digested with Hind III and Eco RI to isolate the 1.1 kb kappa constant region gene. Plasmid pIC19H was linearized by digestion with Eco RI. The 1.65 kb PDGF $\beta$ -R fragment, 25 the 1.1 kb human kappa constant region fragment and the linearized pIC19H were joined in a three part ligation. The resultant plasmid, pSDL112, was digested with Bam HI and Cla I to isolate the 2.75 kb fragment. Plasmid p $\mu$ PRE8 was linearized with Bgl II and Cla I. The 2.75 kb 30 fragment and the linearized p $\mu$ PRE8 were joined by ligation. The resultant plasmid was designated pSDL114 (Figure 7).

Plasmid pSDL114 was linearized by digestion with Cla I and was cotransfected with Pvu I-digested p416 into 35 SP2/0-Ag14 (ATCC CRL 1581) by electroporation using the method essentially described by Neumann et al. (EMBO J. 1: 841-845, 1982). (Plasmid p416 comprises the Adenovirus 5

ori, SV40 enhancer, Adenovirus 2 major late promoter, Adenovirus 2 tripartite leader, 5' and 3' splice sites, the DHFR<sup>r</sup> cDNA, the SV40 polyadenylation signal and pML-1 (Lusky and Botchan, Nature 293: 79-81, 1981) vector sequences.) Transfectants were selected in growth medium containing methotrexate.

Media from drug resistant clones were tested for the presence of secreted PDGF  $\beta$ -receptor analogs by enzyme-linked immunosorbant assay (ELISA). Ninety-six well assay plates were prepared by incubating 100  $\mu$ l of 1  $\mu$ g/ml polyclonal goat anti-human kappa chain (Cappel Laboratories, Melvern, PA) diluted in phosphate buffered saline (PBS; Sigma) overnight at 4°C. Excess antibody was removed by three washes with 0.5% Tween 20 in PBS. One hundred microliters of spent media was added to each well, and the well were incubated for one hour at 4°C. Unbound proteins were removed by eight washes with 0.5% Tween 20 in PBS. One hundred microliters of peroxidase-conjugated goat anti-human kappa antibody (diluted 1:1000 in a solution containing 5% chicken serum (GIBCO-BRL) + 0.5% Tween 20 in PBS) was added to each well and the wells were incubated for one hour at 4°C. One hundred microliters of chromophore (100  $\mu$ l ABTS (2,2'-Azinobis(3-ethylbenzothiazoline sulfonic acid) diammonium salt; Sigma) + 1  $\mu$ l 30% H<sub>2</sub>O<sub>2</sub> + 12.5 ml citrate/phosphate buffer (9.04 g/l citric acid, 10.16 g/l Na<sub>2</sub>HPO<sub>4</sub>)) was added to each well, and the wells were incubated to thirty minutes at room temperature. The samples were measured at 405 nm. The results of the assay showed that the PDGF $\beta$ -R analog secreted by the transfectants contained an immunoglobulin light chain.

Spent media from drug resistant clones was also tested for the presence of secreted PDGF  $\beta$ -receptor analogs by immunoprecipitation. Approximately one million drug resistant transfectants were metabolically labeled by growth in DMEM medium lacking cysteine + 2% calf serum for 18 hours at 37°C in the presence of 50  $\mu$ CI <sup>35</sup>S-cysteine.

Media was harvested from the labeled cells and 250  $\mu$ l of the spent media was assayed by immunoprecipitation with the anti-PDGF  $\beta$ -receptor antibody PR7212 to detect the presence of metabolically labeled PDGF  $\beta$ -receptor analogs.

- 5 PR7212, diluted in PBS, was added to the media to a final concentration of 2.5  $\mu$ g per 250  $\mu$ l spent media. Five microliters of rabbit anti-mouse Ig diluted in PBS was added to the PR7212/media mixtures. The immunocomplexes were precipitated by the addition of 50  $\mu$ l 10% fixed Staph  
10 A (weight/volume in PBS). The immunocomplexes were analyzed on 8% SDS-polyacrylamide gels followed by autoradiography overnight at -70°C. The results of the immunoprecipitation showed that the PDGF  $\beta$ -receptor analog secreted by the transfectants was bound by the anti-PDGF  
15  $\beta$ -receptor antibody. The combined results of the ELISA and immunoprecipitation assays showed that the PDGF  $\beta$ -receptor analog secreted by the transfectants contained both the PDGF  $\beta$ -receptor ligand-binding domain and the human light chain constant region.

20

C. Cotransfection of pSDL114 with an immunoglobulin heavy chain

Plasmid pSDL114 was cotransfected with p $\phi$ 5V<sub>H</sub>huC $\gamma$ 1M-neo, which encodes a neomycin resistance gene expression unit and a complete mouse/human chimeric immunoglobulin heavy chain gene expression unit.

Plasmid p $\phi$ 5V<sub>H</sub>huC $\gamma$ 1M-neo was constructed as follows. The mouse immunoglobulin heavy chain gene was isolated from a lambda genomic DNA library constructed  
30 from the murine hybridoma cell line NR-ML-05 (Serafini et al., Eur. J. Nucl. Med. 14: 232, 1988) using an oligonucleotide probe designed to span the V<sub>H</sub>/D/J<sub>H</sub> junction (5' GCA TAG TAG TTA CCA TAT CCT CTT GCA CAG 3'; Sequence ID Number 33). The human immunoglobulin gamma-1  
35 C gene was isolated from a human genomic library using a cloned human gamma-4 constant region gene (Ellison et al., DNA 1: 11-18, 1981). The mouse immunoglobulin variable

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region was isolated as a 5.3 kb Sst I-Hind III fragment from the original phage clone and the human gamma-1 C gene was obtained from the original phage clone as a 6.0 kb Hind III-Xho I fragment. The chimeric gamma-1 C gene was  
5 created by joining the V<sub>H</sub> and C<sub>H</sub> fragments via the common Hind III site and incorporating them with the *E. coli* neomycin resistance gene expression unit into pIC19H to yield pΦ5V<sub>H</sub>huc<sub>γ</sub>1M-neo.

Plasmid pSDL114 was linearized by digestion with  
10 Cla I and was co-transfected into SP2/O-Ag14 cells with Asp 718 linearized pΦ5V<sub>H</sub>huc<sub>γ</sub>1M-neo. The transfectants were selected in growth medium containing methotrexate and neomycin. Media from drug-resistant clones were tested for their ability to bind PDGF in a competition binding  
15 assay.

The competition binding assay measured the amount of <sup>125</sup>I-PDGF left to bind to human dermal fibroblast cells after preincubation with the spent media from pSDL114-pΦ5V<sub>H</sub>huc<sub>γ</sub>1M-neo transfected cells. The media  
20 were serially diluted in binding medium (Table 4). The dilutions were mixed with 0.5 ng of iodinated PDGF-BB or iodinated PDGF-AA, and the mixtures were incubated for two hours at room temperature. Three hundred micrograms of unlabeled PDGF-BB or unlabeled PDGF-AA was added to one  
25 tube from each series. The sample mixtures were added to 24 well plates containing confluent human dermal fibroblast cells. The cells were incubated with the mixture for four hours at 4°C. The supernatants were aspirated from the wells, and the wells were rinsed three  
30 times with phosphate buffered saline that was held at 4°C (PBS; Sigma, St. Louis, Mo.). Five hundred microliters of PBS + 1% NP-40 was added to each well, and the plates were shaken on a platform shaker for five minutes. The cells were harvested and the amount of iodinated PDGF was  
35 determined. The results of the competition binding assay showed that the protein produced from pSDL114-pΦ5V<sub>H</sub>huc<sub>γ</sub>1M-

neo transfected cells was able to competitively bind PDGF-BB but did not bind PDGF-AA.

The PDGF  $\beta$ -receptor analog produced from a pSDL114-p $\phi$ 5V<sub>H</sub>huC $\gamma$ 1M-neo transfectant was assayed to determine if the receptor analog was able to bind PDGF-BB with high affinity. Eight and one half milliliters of spent media containing the PDGF $\beta$ -R analogs from a pSDL114-p $\phi$ 5V<sub>H</sub>huC $\gamma$ 1M-neo transfectant was added to 425  $\mu$ l of Sepharose Cl-4B-Protein A beads (Sigma, St. Louis, MO), and the mixture was incubated for 10 minutes at 4°C. The beads were pelleted by centrifugation and washed with binding medium (Table 4). Following the wash the beads were resuspended in 8.5 ml of binding media, and 0.25 ml aliquots were dispensed to 1.5 ml tubes. Binding reactions were prepared by adding iodinated PDGF-BB<sub>Tyr</sub> (Example 18.F.) diluted in DMEM + 10% fetal calf serum to the identical aliquots of receptor-bound beads to final PDGF-BB<sub>Tyr</sub> concentrations of between 4.12 pM and 264 pM. Nonspecific binding was determined by adding a 100 fold excess of unlabeled BB to an identical set of binding reactions. Mixtures were incubated overnight at 4°C.

The beads were pelleted by centrifugation, and unbound PDGF-BB was removed with three washes in PBS. The beads were resuspended in 100  $\mu$ l of PBS and were counted. Results of the assay showed that the PDGF $\beta$ -R analog was able to bind PDGF-BB with high affinity.

#### D. Construction of pSDL113.

As shown in Figure 8, the DNA sequence encoding the extracellular domain of the PDGF  $\beta$ -receptor was joined with the DNA sequence encoding a human immunoglobulin heavy chain constant region joined to a hinge sequence. Plasmid pSDL110 was digested with Eco RI and Hind III to isolate the 1.65 kb PDGF $\beta$ -R fragment. Plasmid pICHu $\gamma$ -1M was used as the source of the heavy chain constant region and hinge region. Plasmid pICHu $\gamma$ -1M comprises the approximately 6 kb Hind III-Xho I fragment of a human

gamma-1 C gene subcloned into pUC19 that had been linearized by digestion with Hind III and Sal I. Plasmid pICHu<sub>γ</sub>-1M was digested with Hind III and Eco RI to isolate the 6 kb fragment encoding the human heavy chain constant region. Plasmid pIC19H was linearized by digestion with Eco RI. The 1.65 kb PDGF $\beta$ -R fragment, the 6 kb heavy chain constant region fragment and the linearized pIC19H were joined in a three part ligation. The resultant plasmid, pSDL111, was digested with Bam HI to isolate the 10 7.7 kb fragment. Plasmid p $\mu$ PRE8 was linearized with Bgl II and was treated with calf intestinal phosphatase to prevent self-ligation. The 7.7 kb fragment and the linearized p $\mu$ PRE8 were joined by ligation. A plasmid containing the insert in the proper orientation was 15 designated pSDL113 (Figure 8).

Plasmid pSDL113 is linearized by digestion with Cla I and is cotransfected with Pvu I-digested p416 into SP2/0-Ag14 by electroporation. Transfectants are selected in growth medium containing methotrexate.

20 Media from drug resistant clones are tested for the presence of secreted PDGF $\beta$ -R analogs by immunoprecipitation using the method described in Example 12.B.

25 E. Cotransfection of pSDL113 with an Immunoglobulin Light Chain Gene

Plasmid pSDL113 is linearized by digestion with Cla I and was cotransfected with pIC $\phi$ 5V<sub>k</sub>HuC<sub>k</sub>-Neo, which encodes a neomycin resistance gene and a mouse/human 30 chimeric immunoglobulin light chain gene. The mouse immunoglobulin light chain gene was isolated from a lambda genomic DNA library constructed from the murine hybridoma cell line NR-ML-05 (Woodhouse et al., ibid.) using an oligonucleotide probe designed to span the V<sub>k</sub>/J<sub>k</sub> junction 35 (5' ACC GAA CGT GAG AGG AGT GCT ATA A 3'; Sequence ID Number 34). The human immunoglobulin light chain constant region gene was isolated as described in Example 12.B.

The mouse NR-ML-05 immunoglobulin light chain variable region gene was subcloned from the original mouse genomic phage clone into pIC19R as a 3 kb Xba I-Hinc II fragment. The human kappa C gene was subcloned from the original 5 human genomic phage clone into pUC19 as a 2.0 kb Hind III-Eco RI fragment. The chimeric kappa gene was created by joining the NR-ML-05 light chain variable region gene and human light chain constant region gene via the common Sph I site and incorporating them with the *E. coli* neomycin 10 resistance gene into pIC19H to yield pIC $\phi$ 5V $\kappa$ HuC $\kappa$ -Neo (Figure 9).

The linearized pSDL113 and pIC $\phi$ 5V $\kappa$ HuC $\kappa$ -Neo are transfected into SP2/0-Ag14 cells by electroporation. The transfectants are selected in growth medium containing 15 methotrexate and neomycin.

F. Cotransfection of pSDL113 and pSDL114

A clone of SP2/0-Ag14 stably transfected with pSDL114 and p416 was co-transfected with Cla I-digested 20 pSDL113 and Bam HI-digested pICneo by electroporation. (Plasmid pICneo comprises the SV40 promoter operatively linked to the *E. coli* neomycin resistance gene and pIC19H vector sequences.) Transfected cells were selected in growth medium containing methotrexate and G418. Media 25 from drug-resistant clones were tested for their ability to bind PDGF-BB or PDGF-AA in a competition binding assay as described in Example 12.C. The results of the assay showed that the transfectants secreted a PDGF  $\beta$ -receptor analog which was capable of competitively binding PDGF-BB 30 but did not detectably bind to PDGF-AA.

G. Cotransfection of pSDL114 with Fab

A clone of SP2/0-AG14 stably transfected with pSDL114 and p416 was transfected with the Fab region of 35 the human gamma-4 gene ( $\gamma_4$ ) in plasmid p $\phi$ 5V $H$ Fab-neo.

Plasmid p $\phi$ 5V $H$ Fab-neo was constructed by first digesting plasmid p24BRH (Ellison et al., DNA 1: 11, 1988)

was digested with Xma I and Eco RI to isolate the 0.2 kb fragment comprising the immunoglobulin 3' untranslated region. Synthetic oligonucleotides ZC871 (Sequence ID Number 3; Table 1) and ZC872 (Sequence ID Number 4; Table 5 1) were kinased and annealed using essentially the methods described by Maniatis et al. (ibid.). The annealed oligonucleotides ZC871/ZC872 formed an Sst I-Xma I adapter. The ZC871/ZC872 adapter, the 0.2 kb p24BRH fragment and Sst I-Eco RI linearized pUC19 were joined in 10 a three-part ligation to form plasmid p $\gamma$ 43'. Plasmid p $\gamma$ 43' was linearized by digestion with Bam HI and Hind III. Plasmid p24BRH was cut with Hind III and Bgl II to isolate the 0.85 kb fragment comprising the C<sub>H</sub>1 region. The p $\gamma$ 43' fragment and the Hind III-Bgl II p24BRH fragment were 15 joined by ligation to form plasmid p $\gamma$ 4Fab. Plasmid p $\gamma$ 4Fab was digested with Hind III and Eco RI to isolate the 1.2 kb fragment comprising  $\gamma$ 4Fab. Plasmid pICneo, comprising the SV40 promoter operatively linked to the *E. coli* neomycin resistance gene and pIC19H vector sequences, was 20 linearized by digestion with Sst I and Eco RI. Plasmid p $\phi$ 5V<sub>H</sub>, comprising the mouse immunoglobulin heavy chain gene variable region and pUC18 vector sequences, was digested with Sst I and Hind III to isolate the 5.3 kb V<sub>H</sub> fragment. The linearized pICneo was joined with the 5.3 25 kb Sst I-Hind III fragment and the 1.2 kb Hind III-Eco RI fragment in a three-part ligation. The resultant plasmid was designated p $\phi$ 5V<sub>H</sub>Fab-neo (Figure 10).

A pSDL114/p416-transfected SP2/0-AG14 clone was transfected with Sca I-linearized p $\phi$ 5V<sub>H</sub>Fab-neo. 30 Transfected cells were selected in growth medium containing methotrexate and G418. Media from drug-resistant clones were tested for their ability to bind PDGF in a competition binding assay as described in Example 12.C. The results of the assay showed that the 35 PDGF  $\beta$ -receptor analog secreted from the transfectants was capable of competitively binding PDGF-BB.

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H. Cotransfection of pSDL114 with Fab'

A stably transfected SP2/0-AG14 isolate containing pSDL114 and p416 was transfected with plasmid pWKI, which contained the Fab' portion of an 5 immunoglobulin heavy chain gene. Plasmid pWKI was constructed as follows.

The immunoglobulin gamma-1 Fab' sequence, comprising the C<sub>H</sub>1 and hinge regions sequences, was derived from the gamma-1 gene clone described in Example 10 12.C. The gamma-1 gene clone was digested with Hind III and Eco RI to isolate the 3.0 kb fragment, which was — subcloned into Hind III-Eco RI linearized M13mp19. Single-stranded template DNA from the resultant phage was subjected to site-directed mutagenesis using 15 oligonucleotide ZC1447 (Sequence ID Number 9; Table 1) and essentially the method of Zoller and Smith (*ibid.*). A phage clone was identified having a ZC1447 induced deletion resulting in the fusion of the hinge region to a DNA sequence encoding the amino acids Ala-Leu-His-Asn-His- 20 Tyr-Thr-Glu-Ser-Leu-Ser-Leu-Ser-Pro-Gly-Lys (Sequence ID Number 31) followed in-frame by a stop codon. Replicative form DNA from a positive phage clone was digested with Hind III and Eco RI to isolate the 1.9 kb fragment comprising the C<sub>H</sub>1 and hinge regions. Plasmid 25 pφ5V<sub>H</sub> was digested with Sst I and Hind III to isolate the 5.3 kb fragment comprising the mouse immunoglobulin heavy chain gene variable region. Plasmid pICneo was linearized by digestion with Sst I and Eco RI. The linearized pICneo was joined with the 5.3 kb Hind III-Sst I fragment and the 30 1.9 kb Hind III-Eco RI fragment in a three-part ligation. The resultant plasmid was designated pWKI (Figure 10).

An SP2/0-AG14 clone stably transfected with pSDL114 and p416 was transfected with Asp 718-linearized pWKI. Transfected cells were selected by growth in medium 35 containing methotrexate and G418. Media samples from transfected cells were assayed using the competition assay described in Example 12.C. Results from the assays showed

that the transfected cells produced a PDGF  $\beta$ -receptor analog capable of competitively binding PDGF-BB.

Example 13

5      Purification and Characterization of PDGF  $\beta$ -Receptor  
Analogs from Mammalian cells Co-transfected With pSDL113  
and pSDL114

A.   Purification of PDGF  $\beta$ -Receptor Analogs

10     The PDGF  $\beta$ -receptor analog was purified from conditioned culture media from a clone of transfected cells grown in a hollow fiber system. The media was passed over a protein-A sepharose column, and the column was washed sequentially with phosphate buffered saline, pH 15 7.2 (PBS; Sigma, St. Louis, MO) and 0.1 M citrate, pH 5.0. The PDGF  $\beta$ -receptor analog was eluted from the protein-A column with 0.1 M citrate pH 2.5 and immediately neutralized by the addition of Tris-base, pH 7.4. The eluate fractions containing PDGF  $\beta$ -receptor analog, as 20 determined by silver stain, were pooled and chromatographed over an S-200 column (Pharmacia LKB Technologies, Inc., Piscataway, NJ) equilibrated with PBS. The peak fractions from the S-200 column were pooled and concentrated on a centriprep-10 concentrator (Amicon). 25 Glycerol (10% final volume) was added to the preparation and the sample frozen at -80°C. PDGF  $\beta$ -receptor analogs purified from pSDL114 + pSDL113 co-transfected cells were termed "tetrameric PDGF  $\alpha$ -receptors".

30    B.   Measurement of The Relative Binding Affinity of Tetrameric PDGF  $\beta$ -Receptor Analog by Soluble Receptor Assay

Purified tetrameric PDGF  $\beta$ -receptor analog was compared to detergent solubilized extracts of human dermal 35 fibroblasts for  $^{125}$ I-labeled PDGF-BB binding activity in a soluble receptor assay essentially as described by Hart et al. (J. Biol. Chem. 262: 10780-10785, 1987). Human dermal

fibroblast cells were extracted at  $20 \times 10^6$  cell equivalents per ml in TNEN extraction buffer (20 mM Tris-HCl, pH 8.0, 100 mM NaCl, 1 mM EDTA, 0.5% Nonidet P-40, 1 mM PMSF, 10% glycerol). Two hundred and fifty thousand PDGF  $\beta$ -receptor-subunits per cell was used to calculate the tetrameric PDGF  $\beta$ -receptor analog number per volume of extract. This value has been previously published by Seifert et al. (J. Biol Chem. 264: 8771-8778, 1989). The PDGF  $\beta$ -receptor analog number was determined from the protein concentration of the PDGF  $\beta$ -receptor analog assuming an average molecular weight of 140 kDa for each immunoglobulin-PDGF  $\beta$ -receptor monomer, and four monomers per tetramer. Thus, each tetrameric molecule contains four receptor molecules.

Increasing amounts of either detergent solubilized extracts of human dermal fibroblast cells or purified PDGF  $\beta$ -receptor analog were incubated with 1ng of  $^{125}$ I-labeled PDGF-BB for one hour at 37°C. The sample was then diluted with 1 ml binding media and was added to monolayers of human dermal fibroblast cells grown in 24-well culture dishes. The samples were incubated for two hours at 4°C. The wells were washed to remove unbound,  $^{125}$ I-labeled PDGF-BB. On half of a milliliter of extraction buffer (PBS + 1% Nonidet P-40) was added to each well followed by a 5 minute incubation. The extraction mixtures were harvested and counted in a gamma counter.

The results showed that the PDGF  $\beta$ -receptor analog had the same relative binding affinity as solubilized PDGF  $\beta$ -receptor-subunit from mammalian cells in a solution phase binding assay.

C. Determination of the Binding Affinity of the PDGF  $\beta$ -Receptor Analog in a Solid Phase Format

The apparent dissociation constant  $K_D(\text{app})$  of the PDGF  $\beta$ -receptor analog was determined essentially as described by Bowen-Pope and Ross (Methods in Enzymology

109: 69-100, 1985), using the concentration of  $^{125}\text{I}$ -labeled PDGF-BB giving half-maximal specific  $^{125}\text{I}$ -labeled PDGF-BB binding. Saturation binding assays to determine the concentration of  $^{125}\text{I}$ -labeled PDGF-BB that gave half-maximal binding to immobilized PDGF  $\beta$ -receptor analog were conducted as follows.

Affinity purified goat anti-human IgG, H- and L-chain (Commercially available from Cappel Labs) was diluted into 0.1 M  $\text{Na}_2\text{HCO}_3$ , pH 9.6 to a concentration of 2  $\mu\text{g}/\text{ml}$ . One hundred microliters of the antibody solution was coated onto each well of 96-well microtiter plates for 18 hours at 4°C. The wells were washed once with ELISA C buffer (PBS + 0.05% Tween-20) followed by an incubation with 175  $\mu\text{l}/\text{well}$  of ELISA B buffer (PBS + 1% BSA + 0.05% Tween-20) to block the wells. The wells were washed once with ELISA B buffer. One hundred microliters of 12.1 ng/ml or 24.3 ng/ml of tetrameric PDGF  $\beta$ -receptor analog protein diluted in ELISA B was added to each well and the plates were incubated for 2 hours at 37°C. Unbound protein was removed from the wells by two washes with ELISA C.  $^{125}\text{I}$ -labeled PDGF-BBTyr (Example 18.F.) was serially diluted into binding media (25 mM HEPES, pH 7.2, 0.25% rabbit serum albumin diluted in HAMs F-12 medium (GIBCO-BRL)), and 100  $\mu\text{l}$  of the dilutions were added to the wells. The plates were incubated for two hours at room temperature. The unbound  $^{125}\text{I}$ -labeled PDGF-BB was removed, and the wells were washed three times with binding media. Following the last wash, 100  $\mu\text{l}$  of 0.1 M citrate, pH 2.5 was added to each well. After five minutes, the citrate buffer was removed, transferred to a tube and counted in a gamma counter. The counts reflect counts of  $^{125}\text{I}$ -labeled PDGF-BBTyr bound by the receptor analog. Nonspecific binding for each concentration of  $^{125}\text{I}$ -labeled PDGF-BBTyr was determined by a parallel assay wherein separate wells coated only with goat anti-human IgG were incubated with the  $^{125}\text{I}$ -labeled PDGF-BB concentrations. Nonspecific binding was determined to be

2.8% of the total input counts per well and averaged 6% of the total counts bound.

Saturation binding assay on 12.1 and 24.3 ng/ml of tetrameric PDGF  $\beta$ -receptor analog gave half-maximal binding at 0.8 and 0.82 ng/ml  $^{125}$ I-labeled PDGF-BB $Tyr$ , respectively. By Scatchard analysis (Scatchard, Ann. NY Acad. Sci 51: 660-667, 1949) these values were shown to correspond to a  $K_D$ (app) of  $2.7 \times 10^{-11}$  which agree with the published values for PDGF receptors on mammalian cells.

Example 14

**Solid Phase Ligand Binding Assay Using the PDGF  $\beta$ -Receptor Analog**

15 A. Solid Phase Radioreceptor Competition Binding Assay

In a solid phase radioreceptor competition binding assay (RRA), the wells of 96-well microtiter plates were coated with 100  $\mu$ l of 2  $\mu$ g/ml affinity purified goat anti-human IgG (Cappel Labs) diluted in 0.1 M  $Na_2HCO_3$ , pH 9.6. After an eighteen hour incubation at 4°C, the wells were washed once with ELISA C. The wells were blocked by incubation for 2 hours at 37°C with 175  $\mu$ l/well ELISA B. The wells were washed once with ELISA B then incubated for 2 hours at 37°C with 50 ng/ml 25 tetrameric PDGF  $\beta$ -receptor analog diluted in ELISA B. The unbound receptor was removed, and the test wells were incubated with increasing concentrations of serially diluted, unlabeled PDGF-BB (diluted in binding media. Following a two hour incubation at room temperature, the 30 wells were washed three times with binding media. One hundred microliters of 5 ng/ml  $^{125}$ I-labeled PDGF-BB $Tyr$  (Example 18.F.) was added to each well, and the plates were incubated for an additional two hours at room temperature. The wells were washed three times with 35 binding media followed by a 5 minute incubation with 100  $\mu$ l/well of 0.1 M citrate, pH 2.5. The samples were harvested and counted in a gamma counter.

Radioreceptor assay (RRA) competition binding curves were generated for PDGF  $\beta$ -receptor analog protein plated at 48.6 ng/ml. The sensitivity of the assays is 1 ng/ml of PDGF-BB, with 8 ng/ml giving 50% inhibition in  $^{125}$ I-PDGF-BB binding, and a working range between 1 and 32 ng/ml of PDGF-BB. The values were similar to those obtained using monolayers of SK-5 cells in an RRA.

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10      B. Use of Tetrameric PDGF  $\beta$ -Receptor Analogs As Antagonists for PDGF-Stimulated Mitogenesis.

A tetrameric PDGF  $\beta$ -receptor analog, purified as described in Example 13, was analyzed for the ability to neutralize PDGF-stimulated mitogenesis in mouse 3T3 cells. Increasing amounts of the purified tetrameric PDGF  $\beta$ -receptor analog were mixed with 5 ng of PDGF. The mixtures were then added to cultures of mouse 3T3 cells. The ability of the PDGF to stimulate a mitogenic response, as measured by the incorporation of  $^3$ H-thymidine, was determined essentially as described (Raines and Ross, 15  
20 Methods in Enzymology 109: 749-773, 1985, which is incorporated by reference herein). The tetrameric PDGF  $\beta$ -receptor analog demonstrated a dose response inhibition of PDGF-BB-stimulated  $^3$ H-thymidine incorporation, while having essentially no effect on PDGF-AA- and PDGF-AB- 25  
25 stimulated  $^3$ H-thymidine incorporation.

C. Binding of Tetrameric PDGF  $\beta$ -receptor Analog to Immobilized PDGF.

A tetrameric PDGF  $\beta$ -receptor analog, purified as 30 described in Example 13, was analyzed for its ability to bind to immobilized PDGF. PDGF-BB (100 ng/ml) was coated onto wells a 96-well microtiter plate, and the plates were incubated 18 hours at 4°C followed by one wash with ELISA C buffer. The wells were incubated for 2 hours 37°C with 35  
35 ELISA B buffer to block the wells. Increasing concentrations of  $^{125}$ I-labeled tetrameric PDGF  $\beta$ -receptor analog, diluted in binding media, was added to the wells

for two hours at room temperature. The wells were washed four times with ELISA C buffer to remove unbound receptor analog. One hundred microliters of 1 M H<sub>2</sub>SO<sub>4</sub> was added to each well and the plates were incubated for five minutes 5 at room temperature. The solution was then harvested and transferred to tubes to be counted in a gamma counter. Nonspecific binding was determined to be less than 10% of the total counts bound.

A receptor competition binding assay was 10 developed using this assay format. The assay was carried out as described above, and simultaneous to the addition of the <sup>125</sup>I-labeled tetrameric PDGF  $\beta$ -receptor analog, increasing amounts of PDGF-AA, AB or BB were added to the PDGF-BB coated wells. Under these conditions, only PDGF-BB 15 was found to significantly block the binding of the labeled PDGF  $\beta$ -receptor analog to the immobilized PDGF-BB.

Example 15

Construction and Expression of PDGFr-R Analogs in Cultured 20 Mouse Myeloma Cells

A. Construction of an optimized PDGFr-R cDNA

The PDGF  $\alpha$ -receptor coding region was optimized for expression in mammalian cells as follows. The 5' end of the cDNA was modified to include an optimized Kozak 25 consensus translation initiation sequence (Kozak, Nuc. Acids Res. 12: 857-872, 1984) and Eco RI and Bam HI sites just 5' of the initiation methionine codon. Oligonucleotides ZC2181, ZC2182, ZC2183 and ZC2184 (Sequence ID Numbers 23, 24, 25 and 26, respectively; 30 Table 1) were designed to form, when annealed, an adapter having an Eco RI adhesive end, a Bam HI restriction site, a sequence encoding a Kozak consensus sequence 5' to the initiation methionine codon, a mammalian codon optimized sequence encoding amino acids 1-42 of <sup>Figures 1A-1D</sup> ~~Reported~~ <sup>Reported</sup> Figure 11, and an 35 Eco RI adhesive end that destroys the Eco RI site within the PDGFr-R coding sequence. The adapter also introduced a diagnostic Cla I site 3' to the initiation methionine

codon. Oligonucleotides ZC2181, ZC2182, ZC2183 and ZC2184 were kinased, annealed and ligated. Plasmid p<sub>a</sub>17B was linearized by partial digestion with Eco RI. The linearized p<sub>a</sub>17B was ligated with the 5 ZC2181/ZC2182/ZC2183/ZC2184 oligonucleotide adapter, and the ligation mixture was transformed into *E. coli*. Plasmid DNA prepared from the transformants was analyzed by restriction analysis and a positive clone having the oligonucleotide adapter in the correct orientation was 10 digested with Eco RI and Pst I to isolate the 1.6 kb fragment. This fragment was subcloned into Eco RI + Pst I-linearized M13mp19. The resultant phage clone was designated 792-8. Single-stranded 792-8 DNA was sequenced to confirm the orientation of the adapter.

15 A fragment encoding the ligand-binding domain of the PDGF  $\alpha$ -receptor (PDGFr-R) was then generated as follows. Restriction sites and a splice donor sequence were introduced at the 3' end of the PDGFr-R extracellular domain by PCR amplification of the 792-8 DNA and 20 oligonucleotides ZC2311 and ZC2392 (Sequence ID Numbers 27 and 30, Table 1). Oligonucleotide ZC2311 is a sense primer encoding nucleotides 1470 to 1489 of ~~Figure 1A~~ of ~~Figure 1B~~. Oligonucleotide ZC2392 is an antisense primer that encodes 25 nucleotides 1759 to 1776 of ~~Figure 1A~~ of ~~Figure 1B~~ followed by a splice donor and Xba I and Hind III restriction sites. The 792-8 DNA was amplified using manufacturer recommended (Perkin Elmer Cetus, Norwalk, CT) conditions and the GeneAmp<sup>TM</sup> DNA amplification reagent kit (Perkin Elmer Cetus), and blunt-ended 329 bp fragment was isolated. The blunt-end 30 fragment was digested with Nco I and Hind III and ligated with Sma I-digested pUC18. A plasmid having an insert with the Nco I site distal to the Hind III site present in the pUC18 polylinker was designated pUC18 Sma-PCR Nco HIII #13. The Hind III site present in the insert was not 35 regenerated upon ligation with the linearized pUC18. Plasmid pUC18 Sma-PCR Nco HIII #13 was digested with Nco I and Hind III to isolate the 355 bp PDGFr-R containing

fragment encoding PDGF $\alpha$ R. Oligonucleotides ZC2351 and ZC2352 (Table 1; Sequence ID Numbers 28 and 29) were kinased and annealed to form an Sst I-Nco I adapter encoding an internal Eco RI site and a Kozak consensus 5 translation initiation site. The 355 bp Nco I-Hind III fragment, the ZC2351/ZC2352 adapter and a 1273 bp Nco I fragment comprising the extracellular domain of PDGF  $\alpha$ -R derived from 792-8 were ligated with Hind III + SstI-digested pUC18 and transformed into *E. coli*. Plasmid DNA 10 was isolated from the transformants and analyzed by restriction analysis. None of the isolates contained the 1273 bp Nco I fragment. A plasmid containing the Nco I-Hind III fragment and the ZC2351/ZC2352 adapter was designated pUC18 Hin Sst A Nco #46. Plasmid pUC18 Hin Sst 15 A Nco #46 was linearized by digestion and joined by ligation with the 1273 bp Nco I fragment comprising the extracellular domain of the PDGF $\alpha$ -R from clone  $\alpha$ 18 R-19. The ligations were transformed into *E. coli*, and plasmid DNA was isolated from the transformants. Analysis of the 20 plasmid DNA showed that only clones with the Nco I fragment in the wrong orientation were isolated. A clone having the Nco I fragment in the wrong orientation was digested with Nco I, religated and transformed into *E. coli*. Plasmid DNA was isolated from the transformants and 25 was analyzed by restriction analysis. A plasmid having the Nco I insert in the correct orientation was digested to completion with Hind III and partially digested with Sst I to isolate the 1.6 kb fragment comprising the extracellular domain of the PDGF $\alpha$ -R preceded by a 30 consensus initiation sequence (Kozak, *ibid.*) and followed by a splice donor site.

#### B. Construction of pPAB7

The DNA sequence encoding the extracellular 35 domain of the PDGF $\alpha$ -R was joined to the immunoglobulin  $\mu$  enhancer-promoter and to a DNA sequence encoding an immunoglobulin light chain constant region. The

immunoglobulin  $\mu$  enhancer-promoter was obtained from plasmid pJH1 which was derived from plasmid PIC $\mu$ PRES (Example 12.A.) by digestion with Eco RI and Sst I to isolate the 2.2 kb fragment comprising the immunoglobulin 5 enhancer and heavy chain variable region promoter. The 2.2 kb Sst I-Eco RI fragment was ligated with Sst I + Eco RI-linearized pUC19. The resulting plasmid, designated pJH1, contained the immunoglobulin enhancer and heavy chain variable region promoter immediately 5' to the pUC19 10 linker sequences. Plasmid pJH1 was linearized by digestion with Sst I and Hind III and joined with the 1.6 kb partial Sst I-Hind III fragment containing the PDGF $\alpha$ -R extracellular domain sequences. The resulting plasmid having the immunoglobulin  $\mu$  enhancer-promoter joined to 15 the PDGF $\alpha$ -R extracellular domain was designated pPAB6. Plasmid pSDL112 was digested with Hind III to isolate the 1.2 kb fragment encoding the immunoglobulin light chain constant region (C $\kappa$ ). The 1.2 kb Hind III fragment was ligated with Hind III-linearized pPAB6. A plasmid having 20 the C $\kappa$  sequence in the correct orientation was designated pPAB7.

#### C. Construction of pPAB9

The partial Sst I-Hind III fragment encoding the 25 extracellular domain of the PDGF $\alpha$ -R was joined to the immunoglobulin heavy chain constant region. For convenience, the internal Xba I site in plasmid pJH1 was removed by digestion with Xba I, blunt-ending with T4 DNA polymerase, and religation. A plasmid which did not 30 contain the internal Xba I site, but retained the Xba I site in the polylinker was designated 11.28.3.6. Plasmid 11.28.3.6 was linearized by digestion with Sst I and Xba I. Plasmid pPAB6 was digested to completion with Hind III and partially digested with Sst I to isolate the 1.6 kb 35 Sst I-Hind III fragment containing the PDGF $\alpha$ -R extracellular domain. Plasmid p $\phi$ SV<sub>H</sub>huc $\gamma$ 1M-neo (Example 12.C.) was digested with Hind III and Xba I to isolate the

6.0 kb fragment encoding the immunoglobulin heavy chain constant region (huC<sub>γ</sub>1M). The Sst I-Hind III-linearized 11.28.3.6, the 1.6 kb Sst I-Hind III PDGF<sub>α</sub>-R fragment and the 6.0 kb Hind III-Xba I huC<sub>γ</sub>1M fragment were ligated to  
5 form plasmid pPAB9.

D. Expression of pPAB9 in Mammalian Cells

Bgl II-linearized pPAB7 and Pvu I-linearized pPAB9 were cotransfected with Pvu I-linearized p416 into  
10 SP2/0-Ag14 cells by electroporation. Transfected cells were initially selected in growth medium containing 50 nM methotrexate and were subsequently amplified in a growth medium containing 100 µM methotrexate. Media from drug resistant clones were tested for the presence of secreted  
15 PDGF α-receptor analogs by enzyme-linked immunosorbant assay (ELISA). Ninety-six well assay plates were prepared by incubating 100 µl of 1 µg/ml monoclonal antibody 292.1.8 which is specific for the PDGF α-receptor diluted in phosphate buffered saline (PBS; Sigma) overnight at 4°C.  
20 Excess antibody was removed by three washes with 0.5% Tween 20 in PBS. One hundred microliters of spent media was added to each well, and the plates were incubated for one hour at 4°C. Unbound proteins were removed by eight washes with 0.5% Tween 20 in PBS. One hundred microliters  
25 of peroxidase-conjugated goat anti-human IgG heavy chain antibody (diluted 1:1000 in a solution containing 5% chicken serum (GIBCO-BRL) + 0.5% Tween 20 in PBS) was added to each well, and the plates were incubated for one hour at 4°C. One hundred microliters of chromophore (100  
30 µl ABTS [2,2'-Azinobis(3-ethylbenz-thiazoline sulfonic acid] diammonium salt; Sigma] + 1 µl 30% H<sub>2</sub>O<sub>2</sub> + 12.5 ml citrate/phosphate buffer [9.04 g/l citric acid, 10.16 g/l Na<sub>2</sub>HPO<sub>4</sub>]) was added to each well, and the wells were incubated for 30 minutes at room temperature. The samples  
35 were measured at 405 nm. The results of the assay showed that the PDGF α-receptor analogs secreted by the transfectants contained an immunoglobulin heavy chain.

Analysis of spent media from transfected cells by Northern analysis, Western analysis and by radioimmunoprecipitation showed that the transfectants did not express a PDGF  $\alpha$ -receptor analog from the pPAB7 construction. Transfectants were subsequently treated as containing only pPAB9.

Drug resistant clones was also tested for the presence of secreted PDGF  $\alpha$ -receptor analogs by immunoprecipitation. For each clone, approximately one million drug resistant transfectants were grown in DMEM lacking cysteine + 2% calf serum for 18 hours at 37°C in the presence of 50  $\mu$ Ci  $^{35}$ S-cysteine. The spent media was harvested from the labeled cells and 250  $\mu$ l of medium from each clone was assayed for binding to the anti-PDGF  $\alpha$ -receptor antibody 292.18. Monoclonal antibody 292.18 diluted in PBS was added to each sample to a final concentration of 2.5  $\mu$ g per 250  $\mu$ l spent media. Five microliters of rabbit anti-mouse Ig diluted in PBS was added to each sample, and the immunocomplexes were precipitated by the addition of 50  $\mu$ l 10% fixed Staph A (weight/volume in PBS). The immunocomplexes were analyzed on 8% SDS-polyacrylamide gels followed by autoradiography overnight at -70°C. The results of the immunoprecipitation showed that the PDGF  $\alpha$ -receptor analog secreted by the transfectants was bound by the anti-PDGF  $\alpha$ -receptor antibody. The combined results of the ELISA and immunoprecipitation assays showed that the PDGF  $\alpha$ -receptor analog secreted by the transfectants contained both the PDGF  $\alpha$ -receptor ligand-binding domain and the human heavy chain.

Spent medium from drug-resistant clones were tested for their ability to bind PDGF in a competition binding assay essentially as described in Example 12.C. The results of the assay showed that the transfectants secreted a PDGF  $\alpha$ -receptor analog capable of binding PDGF-AA. A clone containing the pPAB9 was designated 3.17.1.57.

E. Co-expression of pPAB7 and pPAB9 in Mammalian Cells

Bgl II-linearized pPAB7 and Bam HI-linearized pICneo were cotransfected into clone 3.17.1.57, and 5 transfected cells were selected in the presence of neomycin. Media from drug resistant cells were assayed for the presence of immunoglobulin heavy chain, immunoglobulin light chain and the PDGF  $\alpha$ -receptor ligand-binding domain by ELISA essentially as described above. 10 Briefly, ninety-six well assay plates were prepared by incubating 100  $\mu$ l of 1  $\mu$ g/ml goat anti-human IgG Fc antibody (Sigma) or 100  $\mu$ l of 1  $\mu$ g/ml 292.18 overnight at 4°C. Excess antibody was removed by three washes with 0.5% Tween 20 in PBS. One hundred microliters of spent 15 media was added to each well of each plate, and the plates were incubated for one hour at 4°C. Unbound proteins were removed by eight washes with 0.5% Tween 20 in PBS. One hundred microliters of peroxidase-conjugated goat anti-human IgG antibody (diluted 1:1000 in a solution 20 containing 5% chicken serum (GIBCO-BRL) + 0.5% Tween 20 in PBS) was added to each well of the plate coated with the anti-Fc antibody, and 100  $\mu$ l of peroxidase-conjugated goat anti human kappa antibody (diluted 1:1000 in a solution containing 5% chicken serum (GIBCO-BRL) + 0.5% Tween 20 in 25 PBS) was added to each well of the plate coated with 292.18. The plates were incubated for one hour at 4°C. One hundred microliters of chromophore (100  $\mu$ l ABTS [2,2'-Azinobis(3-ethylbenz-thiazoline sulfonic acid) diammonium salt; Sigma] + 1  $\mu$ l 30% H<sub>2</sub>O<sub>2</sub> + 12.5 ml citrate/phosphate 30 buffer [9.04 g/l citric acid, 10.16 g/l Na<sub>2</sub>HPO<sub>4</sub>]) was added to each well of each plate, and the plates were incubated to 30 minutes at room temperature. The samples were measured at 405 nm, the wavelength giving maximal absorbance of the chromogenic substrate, to identify 35 clones having absorbances higher than background indicating the presence of immunoglobulin heavy chain. Clones that gave positive results in both ELISA assays

(showing that the clones produced proteins containing heavy chain regions, light chain constant regions and the PDGF  $\alpha$ -receptor ligand-binding region) were selected for further characterization.

5 Drug resistant clones that were positive for both ELISA assays were subsequently tested for the presence of secreted PDGF  $\alpha$ -receptor analogs by immunoprecipitation. For each positive clone, approximately one million drug resistant transfectants  
10 were grown in DMEM lacking cysteine + 2% calf serum for 18 hours at 37°C in the presence of 50  $\mu$ CI  $^{35}$ S-cysteine. The spent media was harvested from the labeled cells and 250  $\mu$ l of medium from each clone was assayed for binding to monoclonal antibody 292.18. Monoclonal antibody 292.18  
15 diluted in PBS was added to each sample to a final concentration of 2.5  $\mu$ g. Five microliters of rabbit anti-mouse Ig diluted in PBS was added to each sample and the immunocomplexes were precipitated by the addition of 50  $\mu$ l 10% fixed Staph A (weight/volume in PBS). The  
20 immunocomplexes were analyzed on 8% SDS-polyacrylamide gels followed by autoradiography overnight at -70°C. The results of the immunoprecipitation showed that the PDGF  $\alpha$ -receptor analog secreted by the transfectants was bound by the anti-PDGF  $\alpha$ -receptor antibody. The combined results  
25 of the ELISA and immunoprecipitation assays showed that the PDGF  $\alpha$ -receptor analog secreted by the transfectants contained the PDGF  $\alpha$ -receptor ligand-binding domain, the human heavy chain and the human light chain constant region. A clone that secreted a PDGF  $\alpha$ -receptor analog  
30 that was positive for both the above-described ELISA assays and the immunoprecipitation assay was designated 5.6.2.1.

**Example 16**  
**Purification and Characterization of PDGF  $\alpha$ -Receptor  
Analogs**

**5 A. Purification of PDGF  $\alpha$ -Receptor Analogs From Clone  
3.17.1.57**

The PDGF  $\alpha$ -Receptor analog was purified from the conditioned culture media of clone 3.17.1.57 by cycling cell-conditioned medium over an immunoaffinity column composed of monoclonal antibody 292.18 bound to a CNBr-activated Sepharose 4B resin, which is specific for the PDGF  $\alpha$ -receptor. The column was washed with PBA, then eluted with 0.1 M citrate, pH 3.0. The peak column fractions containing the  $\alpha$ -receptor were pooled, neutralized to pH 7.2 by the addition of 2 M Tris, pH 7.4, then passed over a protein-A Sepharose column. This column was washed sequentially with PBS, then with 0.1 M citrate, pH 5.0. The PDGF  $\alpha$ -receptor analog was then eluted with 0.1 M citrate, pH 3.0. The peak eluate fractions were pooled, and glycerol was added to a final concentration of 10%. The sample was concentrated on a centriprep 10 concentrator (Amicon). The PDGF  $\alpha$ -receptor analog purified from clone 3.17.1.57 was termed a "dimeric PDGF  $\alpha$ -receptor analog".

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**B. Purification of PDGF  $\alpha$ -Receptor Analogs From Clone  
5.6.2.1**

The PDGF  $\alpha$ -receptor analog was purified from the conditioned culture media of clone 5.6.2.1 by cycling cell-conditioned medium over the immunoaffinity column described above. The column was washed with PBS then eluted with 0.1 M citrate, pH 3.0. The peak column fractions containing the  $\alpha$ -receptor were pooled, neutralized to pH 7.2 by the addition of 2 M Tris (what pH 7.4), then passed over a protein-A sepharose column. This column was washed sequentially with PBS then with 0.1 M

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citrate, pH 5.0. The PDGF  $\alpha$ -receptor analog was then eluted with 0.1 M citrate, pH 3.0. The peak eluate fractions were pooled and glycerol was added to a final concentration of 10%. The sample was concentrated on a 5 centriprep 10 concentrator. The PDGF  $\alpha$ -receptor analogs purified from clone 5.6.2.1 was termed a "tetrameric PDGF  $\alpha$ -receptor analog".

Example 17

10 A. Use of the PDGF  $\alpha$ -receptor Analogs in Ligand Binding Studies

Purified tetrameric PDGF  $\alpha$ -receptor analog and purified dimeric PDGF  $\alpha$ -receptor analog were compared to monolayers of a control cell line of canine kidney 15 epithelial cells, which do not naturally express the PDGF  $\alpha$ -receptor, transfected with the human PDGF  $\alpha$ -receptor cDNA for ligand binding activity. The dissociation constant ( $K_d$ ) of the receptor preparations was determined by saturation binding and subsequent Scatchard analysis.

20 Ligand binding of the purified PDGF  $\alpha$ -receptor analogs was determined using a solid phase binding assay. Affinity-purified goat anti-human IgG was diluted to a concentration of 2  $\mu$ g/ml in 0.1 M  $Na_2HCO_3$ , pH 9.6 and 100  $\mu$ l/well of the solution was used to coat 96-well 25 microtiter plates for 18 hours at 4°C. Excess antibody was removed from the wells with one wash with ELISA C buffer (PBS, 0.05% Tween-20). The plates were incubated with 175  $\mu$ l/well of ELISA B buffer (PBS, 1% BSA, 0.05% Tween-20) to block the wells, followed by two washes with 30 ELISA C buffer. One hundred microliters of 50 ng/ml PDGF  $\alpha$ -receptor analog (dimeric or tetrameric) diluted in ELISA buffer B was added to each well and the plates were incubated over night at 4°C. Unbound protein was removed from the wells with two washes with ELISA buffer B.  $^{125}I$ -35 labeled PDGF-AA was serially diluted in binding media (Hams F-12, 25 mM HEPES pH 7.2, 0.25% rabbit serum albumin), and 100  $\mu$ l of each dilution was added to the

wells. The samples were incubated for two hours at room temperature. Unbound  $^{125}\text{I}$ -labeled PDGF-AA was removed with three washes with binding media. One hundred microliters of 0.1 M citrate, pH 2.5 was added to each 5 well, and the plates were incubated for five minutes. After the incubation, the citrate buffer was removed and transferred to a tube for counting in a gamma counter. Nonspecific binding for each concentration of  $^{125}\text{I}$ -labeled PDGF-AA was determined by a parallel assay wherein 10 separate wells coated only with goat anti-human IgG were incubated with the  $^{125}\text{I}$ -labeled PDGF-AA samples.

A saturation binding assay was performed on alpha T-7 cells transfected with the PDGF  $\alpha$ -receptor. The cells were grown to confluence in 24-well culture plates. 15 The cells were washed one time with binding media. Iodinated PDGF-AA was serially diluted in binding media. One milliliter of each dilution was added to the wells, and the plates were incubated for 3 hours at  $4^\circ\text{C}$ . Unbound  $^{125}\text{I}$ -labeled PDGF-AA was removed and the cells were washed 20 three times with binding media. PBS containing 1% Triton X-100 was added to the cells for 5 minutes. The extracts were harvested and counted in a gamma counter. Nonspecific binding was determined at a single concentration of  $^{125}\text{I}$ -labeled PDGF-AA using a 500-fold excess PDGF-BB.

The dissociation constants determined by Scatchard analysis (*ibid.*) of the saturation binding assays for the tetrameric PDGF  $\alpha$ -receptor analog, dimeric PDGF  $\alpha$ -receptor analog and the control cells (Table 5).

Table 5

Dissociation Constants for the Tetrameric PDGF  $\alpha$ -Receptor,  
the Dimeric PDGF  $\alpha$ -receptor and control cells Transfected  
with the PDGF  $\alpha$ -receptor

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	<u>Receptor</u>	<u>kD</u>
	Tetrameric PDGF $\alpha$ -receptor analog	- $1.6 \times 10^{-11}$
	Dimeric PDGF $\alpha$ -receptor analog	- $8.51 \times 10^{-11}$
10	Control cells[PDGF $\alpha$ -receptor]	- $3.7 \times 10^{-11}$

A solid-phase competition binding assay was established using the tetrameric PDGF  $\alpha$ -receptor analog. Ninety six-well microtiter plates were coated with goat 15 anti-human IgG (2  $\mu$ g/ml), the wells blocked with ELISA B buffer, 50 ng/ml of purified tetrameric PDGF  $\alpha$ -receptor analog diluted in binding media was added, and the plates were incubated two hours at room temperature. Unbound receptor was removed and the wells were washed with 20 binding media. The plates were incubated for two hours at room temperature with increasing concentrations of either PDGF-AA or PDGF-BB diluted in binding media. The wells were washed, then incubated for two hours at room 25 temperature with 3 ng/ml  $^{125}$ I-labeled PDGF-AA diluted in binding media. Unbound labeled PDGF-AA was removed, the wells were subsequently washed with binding media, and the bound, labeled PDGF-AA was harvested by the addition of 0.1 M citrate, pH 2.5, as described for the saturation 30 binding studies. PDGF-AB, PDGF-AA and PDGF-BB were found to compete for receptor binding with  $^{125}$ I-PDGF-AA.

B. Use of Tetrameric PDGF  $\alpha$ -Receptor Analogs As Antagonists for PDGF-Stimulated Mitogenesis.

A dimeric PDGF  $\alpha$ -receptor analog, purified as 35 described in Example 16.B., was analyzed for the ability to neutralize PDGF-stimulated mitogenesis in mouse 3T3 cells. Increasing amounts of the purified tetrameric PDGF

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$\alpha$ -receptor analog were mixed with PDGF-AA, -AB or -BB ranging .6 to 5 ng. The mixtures were then added to cultures of confluent mouse 3T3 cells. The ability of the PDGF to stimulate a mitogenic response, as measured by the incorporation of  $^3\text{H}$ -thymidine, was determined essentially as described (Raines and Ross, Methods in Enzymology 109: 749-773, 1985, which is incorporated by reference herein). The dimeric PDGF  $\alpha$ -receptor analog demonstrated a dose response inhibition of PDGF-stimulated  $^3\text{H}$ -thymidine incorporation for all three isoforms of PDGF.

C. Inverse Ligand-Receptor Radioreceptor Assay

An inverse ligand-receptor radioreceptor assay was designed to screen for the presence of PDGF-BB, PDGF-BB binding proteins, PDGF-BB related molecules, and PDGF- $\beta$  receptor antagonists in test samples. PDGF-BB (100 ng/ml) was coated onto the walls of 96-well microtiter plates, and the plates were incubated at 4°C for 16 hours. The wells were washed once with ELISA C buffer and then incubated with ELISA B buffer to block the nonspecific binding sites. To the wells were added 50  $\mu\text{l}$  of either PDGF standard or a test sample and 50  $\mu\text{l}$  of  $^{125}\text{I}$ -labeled tetrameric PDGF  $\beta$ -receptor analog. The samples were incubated for one hour at room temperature. The wells were washed once with ELISA C buffer, and 0.1 M citrate, pH 2.5 containing 1% NP-40 was added to each well to disrupt the ligand-receptor analog bond and elute the bound receptor analog. The acid wash was collected and counted in a gamma counter. The presence of PDGF or a molecule which mimics PDGF or otherwise interferes with the binding of the well-bound PDGF-BB with its receptor will cause a decrease in the binding of the radiolabeled tetrameric PDGF  $\beta$ -receptor. Using this assay, PDGF-BB was found to inhibit receptor binding while PDGF-AA and PDGF-AB caused no significant decrease in receptor binding.

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Example 18

## Assay Methods

## A. Preparation of Nitrocellulose Filters for Colony Assay

5 Colonies of transformants were tested for secretion of PDGF  $\beta$ -receptor analogs by first growing the cells on nitrocellulose filters that had been laid on top of solid growth medium. Nitrocellulose filters (Schleicher & Schuell, Keene, NH) were placed on top of  
10 solid growth medium and were allowed to be completely wetted. Test colonies were patched onto the wetted filters and were grown at 30°C for approximately 40 hours. The filters were then removed from the solid medium, and the cells were removed by four successive rinses with  
15 Western Transfer Buffer (Table 4). The nitrocellulose filters were soaked in Western Buffer A (Table 4) for one hour at room temperature on a shaking platform with two changes of buffer. Secreted PDGF $\beta$ -R analogs were visualized on the filters described below.

## 20 B. Preparation of Protein Blot Filters

A nitrocellulose filter was soaked in Western Buffer A (Table 4) without the gelatin and placed in a Minifold (Schleicher & Schuell, Keene, NH). Five  
25 milliliters of culture supernatant was added without dilution to the Minifold wells, and the liquid was allowed to pass through the nitrocellulose filter by gravity. The nitrocellulose filter was removed from the minifold and was soaked in Western Buffer A (Table 3) for one hour on a  
30 shaking platform at room temperature. The buffer was changed three times during the hour incubation.

## C. Preparation of Western Blot Filters

The transformants were analyzed by Western blot,  
35 essentially as described by Towbin et al. (Proc. Natl. Acad. Sci. USA 76: 4350-4354, 1979) and Gordon et al. (U.S. Patent No. 4,452,901). Culture supernatants from

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appropriately grown transformants were diluted with three volumes of 95% ethanol. The ethanol mixtures were incubated overnight at -70°C. The precipitates were spun out of solution by centrifugation in an SS-24 rotor at

5 18,000 rpm for 20 minutes. The supernatants were discarded and the precipitate pellets were resuspended in 200  $\mu$ l of dH<sub>2</sub>O. Two hundred microliters of 2x loading buffer (Table 4) was added to each sample, and the samples were incubated in a boiling water bath for 5 minutes.

10 The samples were electrophoresed in a 15% sodium dodecylsulfate polyacrylamide gel under non-reducing conditions. The proteins were electrophoretically transferred to nitrocellulose paper using conditions described by Towbin et al. (ibid.). The nitrocellulose 15 filters were then incubated in Western Buffer A (Table 4) for 75 minutes at room temperature on a platform rocker.

D. Processing the Filters for Visualization with Antibody

20 Filters prepared as described above were screened for proteins recognized by the binding of a PDGF  $\beta$ -receptor specific monoclonal antibody, designated PR7212. The filters were removed from the Western Buffer A (Table 4) and placed in sealed plastic bags containing a 25 10 ml solution comprising 10  $\mu$ g/ml PR7212 monoclonal antibody diluted in Western Buffer A. The filters were incubated on a rocking platform overnight at 4°C or for one hour at room temperature. Excess antibody was removed with three 15-minute washes with Western Buffer A on a 30 shaking platform at room temperature.

Ten microliters biotin-conjugated horse anti-mouse antibody (Vector Laboratories, Burlingame, CA) in 20 ml Western Buffer A was added to the filters. The filters were re-incubated for one hour at room temperature on a 35 platform shaker, and unbound conjugated antibody was removed with three fifteen-minute washes with Western Buffer A.

The filters were pre-incubated for one hour at room temperature with a solution comprising 50  $\mu$ l Vectastain Reagent A (Vector Laboratories) in 10 ml of Western Buffer A that had been allowed to incubate at room temperature for 30 minutes before use. The filters were washed with one quick wash with distilled water followed by three 15-minute washes with Western Buffer B (Table 4) at room temperature. The Western Buffer B washes were followed by one wash with distilled water.

10 During the preceding wash step, the substrate reagent was prepared. Sixty mg of horseradish peroxidase reagent (Bio-Rad, Richmond, CA) was dissolved in 20 ml HPLC grade methanol. Ninety milliliters of distilled water was added to the dissolved peroxidase followed by 15 2.5 ml 2 M Tris, pH 7.4 and 3.8 ml 4 M NaCl. One hundred microliters of 30%  $H_2O_2$  was added just before use. The washed filters were incubated with 75 ml of substrate and incubated at room temperature for 10 minutes with vigorous shaking. After the 10 minute incubation, the buffer was 20 changed, and the filters were incubated for an additional 10 minutes. The filters were then washed in distilled water for one hour at room temperature. Positives were scored as those samples which exhibited coloration.

25 E. Processing the Filters For Visualization with an Anti-Substance P Antibody

Filters prepared as described above were probed with an anti-substance P antibody. The filters were removed from the Western Buffer A and rinsed with Western 30 transfer buffer, followed by a 5-minute wash in phosphate buffered saline (PBS, Sigma, St. Louis, MO). The filters were incubated with a 10 ml solution containing 0.5 M 1-ethyl-3-3-dimethylamino propyl carbodiimide (Sigma) in 1.0 M  $NH_4Cl$  for 40 minutes at room temperature. After 35 incubation, the filters were washed three times, for 5 minutes per wash, in PBS. The filters were blocked with 2% powdered milk diluted in PBS.

The filters were then incubated with a rat anti-substance P monoclonal antibody (Accurate Chemical & Scientific Corp., Westbury, NY). Ten microliters of the antibody was diluted in 10 ml of antibody solution (PBS 5 containing 20% fetal calf serum and 0.5% Tween-20). The filters were incubated at room temperature for 1 hour. Unbound antibody was removed with four 5-minute washes with PBS.

10 The filters were then incubated with a biotin-conjugated rabbit anti-rat peroxidase antibody (Cappel Laboratories, Melvern, PA). The conjugated antibody was diluted 1:1000 in 10 ml of antibody solution for 2 hours at room temperature. Excess conjugated antibody was removed with four 5-minute washes with PBS.

15 The filters were pre-incubated for 30 minutes at room temperature with a solution containing 50 µl Vectastain Reagent A (Vector Laboratories) and 50 µl Vectastain Reagent B (Vector Laboratories) in 10 ml of antibody solution that had been allowed to incubate for 30 20 minutes before use. Excess Vectastain reagents were removed by four 5-minute washes with PBS.

During the preceding wash step, the substrate reagent was prepared. Sixty milligrams of horseradish peroxidase reagent (Bio-Rad Laboratories, Richmond, CA) 25 was dissolved in 25 ml of HPLC grade methanol. Approximately 100 ml of PBS and 200 µl H<sub>2</sub>O<sub>2</sub> were added just before use. The filters were incubated with the substrate reagent for 10 to 20 minutes. The substrate was removed by a vigorous washing distilled water.

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F. Iodination of PDGF-BB.

A PDGF-BB mutant molecule having a tyrosine replacing the phenylalanine at position 23 (PDGF-BB<sub>Tyr</sub>) was iodinated and subsequently purified, using a purification 35 method which produces <sup>125</sup>I-labeled PDGF-BB with a higher specific activity than primary-labeled material and which was found to substantially decrease the nonspecific binding

component. The PDGF-BB<sub>Tyr</sub> was labeled using the Iodobead method (Pierce Chemical). The labeled protein was gel filtered over a C-25 desalting column (Pharmacia LKB Technologies) equilibrated with 10 mM acetic acid, 0.25%

5 gelatin and 100 mM NaCl. The peak fractions were pooled and pH adjusted to 7.2 by the addition of Tris-base. The labeled mixture was chromatographed over an affinity column composed of PDGF  $\beta$ -receptor analog protein coupled to CnBr-activated Sepharose (Pharmacia LKB Technologies, Inc.). The column was washed with phosphate buffered saline and eluted with 0.1 M citrate, pH 2.5 containing 10 0.25% gelatin. The peak eluate fractions were pooled and assayed by ELISA to determine the PDGF-BB concentration.

Although the foregoing invention has been described in some detail by way of illustration and example for purposes of clarity of understanding, it will be evident that certain changes and modifications may be practiced within the scope of the appended claims.